ORIGINAL RESEARCH PAPER

Orthodontics

COMPARATIVE EVALUATION OF THE HYOID BONE POSITION IN SKELETAL CLASS III SUBJECTS WITH AND WITHOUT CLEFT

KEY WORDS: Hyoid Bone, Cleft, Class III, Mandibular Prognathism

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ABSTRACT

Introduction: Hyoid bone which is considered to play a vital role in maintaining the airway patency is susceptible to positional changes due a variety of functional and morphological variations in crania-facial region especially mandible. Cleft subjects tend to show a class III skeletal pattern chiefly due to retrognathic maxilla and secondary adaptations in mandible unlike the regular skeletal class III subjects without clefts where in there is a prognathic mandible. **Aim:** This Study is conducted to evaluate the hyoid bone position in skeletal class III subjects with and without cleft. **Material and Methods:** This retrospective study was carried out on lateral cephalograms of skeletal class III subjects with (n=19) and without cleft (n=19) along with a control group of class I subjects (n=19). The Class III group was further divided based on the presence or absence of cleft conditions into Class III with cleft and Class III without cleft groups. The effective lengths of the maxilla (Co-point A) and mandible (Co-point B) were evaluated in all groups, and the position of the hyoid bone was assessed using lateral cephalograms, as suggested by Wang et al. **Results:** Maxillo-mandibular relations evaluated with ANOVA & Post Hoc showed a significant difference among the groups. Krushkal Wallis and Mann Whitney test showed Hyoid bone to be located more posteriorly in skeletal class III non cleft subjects **Conclusion:** No significant change in hyoid bone position in cleft subjects compared to class I and class III non cleft subjects in vertical plane. However class III non cleft subjects had significantly posterior positioned hyoid bone.

INTRODUCTION:

The hyoid bone is a U-shaped bone located at the level of the third cervical vertebra in the cervical region and is often considered as sesamoid bone because of its non-attachment to other bones and association with muscles and tendons. The hyoid originates from the cartilage of the 2nd and 3rd branchial arches, whereas the sesamoid bones are formed directly from the connective tissues. It serves as a platform for attachment of various muscles above and below it. These muscles connect the hyoid bone to the cranium, tongue, mandible, larynx and play a crucial role in the array of stomato-gnathic functions[1]. It is often considered a pedestal for mandibular movement owing to its synchronous motion with the mandible. Because of this close association between the hyoid bone, mandible, and other structures, any physiological and anatomical variations in the craniofacial region are likely to affect the hyoid bone position. In amphibians and reptiles, the hyoid bone is mainly involved in supporting the tongue and is often referred to as the tongue bone. In the realm of evolution, as quadrupeds evolved into bipeds, klinorhynchy led to the migration of the lower jaw in a downward and backward direction. Additionally, the hyoid bone has migrated caudally and posteriorly, undergoing changes in both form and position over time to accommodate structural, functional, and evolutionary modifications. Consequently, the position of the hyoid bone is subject to change.

The location of the hyoid bone is known to differ relative to various craniofacial skeletal patterns, with some degree of uncertainty[2-4]. One particular example is Skeletal class III conditions, which may result from a prognathic mandible or retrognathic maxilla. In such cases, the mandible and the hyoid bone take up a more sagittal position within the craniofacial complex[2]. Skeletal class III conditions have a strong genetic predisposition, typically presenting as a prognathism of the mandible, with an incidence rate of 5.33% in Andhra Pradesh[5]. Variants of the MYO1H (rs10850110), BMP3 (rs1390319), GHR (rs2973015, rs6184, rs2973015), FGF7 (rs372127537), FGF10 (rs593307), and SNAI3 genes are commonly reported to be associated with class III [6].

Cleft Lip and Palate is a prevalent craniofacial anomaly that typically results in the impaired growth of the maxilla, leading to a skeletal class III tendency. This condition affects various physiological functions, such as speech, mastication, and deglutition. The hyoid bone, which lies between the manubrium sterni and the mandible and is supported by the supra and infrahyoid muscle groups, plays a crucial role in these functions. In cleft conditions, the altered functional environment can cause changes in the position of the hyoid bone, which is typically found to be more anterior and caudal[7]. Cleft patients often exhibit a skeletal class III tendency, primarily due to a retrognathic maxilla and to a lesser extent, a prognathic mandible. However, it's important to note that a prognathic mandible in cleft cases might be a result of secondary adaptation to structural and functional changes, unlike in non-cleft subjects. The genetic makeup of skeletal class III condition in cleft patients and those without cleft appears to be at opposite ends of the spectrum. While a common multifactorial and polygenic inheritance cannot be ruled out, it is evident that the genetic factors at play are distinct.

The hyoid bone position can be assessed using conventional lateral cephalograms, which are typically taken during orthodontic evaluation for various malocclusions. Considering the significance of the hyoid bone, it is essential to examine its position in skeletal Class III patients with and without cleft conditions to understand the influence of genetic, epigenetic, and environmental factors on the anatomical adaptation of craniofacial structures. This knowledge can be useful in treatment planning. Previous studies[8-10] have investigated the hyoid bone position in various facial patterns, but there is a lack of literature on differentiating the hyoid bone position in Class III and Cleft subjects. Therefore, this study aimed to evaluate the position of the hyoid bone in skeletal Class III subjects with and without clefts.

MATERIALS AND METHODS:

The study was conducted with approval from the institutional review board (xxxxxxxxxx), and pretreatment lateral cephalograms of patients who had undergone treatment were obtained from achieves of department of orthodontics, xxxxxxxxx dental sciences and were retrospectively analyzed. Lateral cephalograms of subjects who were skeletal class I or III, aged between 15 and 25 years, with or without cleft lip and palate, and met the following inclusion criteria were obtained : 1) skeletal class III (ANB < 1°) or skeletal class I (ANB 2° – 4°), 2) good contrast radiographs, 3) no distortions, and 4) no surgical mandibular interventions. The exclusion criteria were 1) poor radiographic quality, 2) radiographs without adequate exposure above the 4th cervical vertebra, and 3) radiographs with altered head posture.

The sample size was determined using G*power 3.1.9.2 software. A sample of 57 patients (19 in each group) was required to detect an effect size of 0.4 at an alpha of 5% and 80% power.

ANB and Beta angle were used to assess sagittal maxillo-mandibular discrepancy on lateral cephalograms, and the samples were divided into skeletal class I and class III groups. The Class III group was further divided based on the presence or absence of cleft conditions into Class III with cleft and Class III without cleft groups. The effective lengths of the maxilla (Co-point A) and mandible (Co-point B) were evaluated in all groups, and the position of the hyoid bone was assessed using lateral cephalograms, as suggested by Wang et al.[11]

All the lateral cephalograms were traced manually by a single researcher and landmarks for locating the position of hyoid bone were identified (Figure 1and 2) and the measurements were tabulated (Table 1). Data obtained were subjected for statistical appraisal using SPSS (Version 20) software.

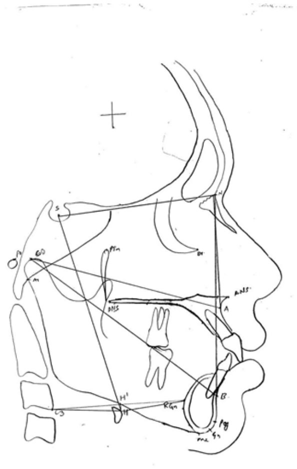

Figure 1: Lateral cephalogram showing the landmarks and measurements

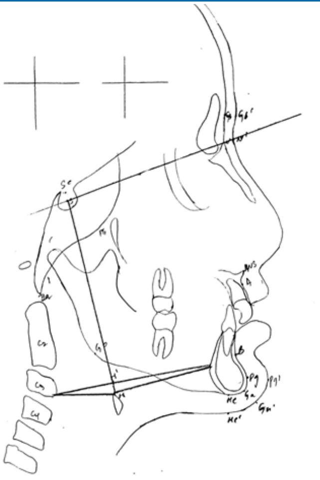

Figure 2: Lateral cephalogram of a cleft patient showing the landmarks and measurements

RESULTS:

Cephalometric data evaluated from the lateral cephalogram with respect to the position of the hyoid bone did not follow a normal distribution, whereas the data for the maxilla-mandibular relationship showed normality. Table 2 and 3 shows the descriptive statistics of the relationship between the maxillary and mandibular skeletal bases and the hyoid bone position.

Maxillo-mandibular relationship was evaluated with ANOVA (Table 4) followed by Tukey's post hoc test (Table 5) to find significant differences among the groups. Nonparametric Kruskal Wallis test (Table 6) and Mann-Whitney test (Table 7) was performed to evaluate the hyoid bone position.

The Table 4 and 5 shows a statistically significant difference among the three groups for the maxillary length with the highest mean of 92.16 ± 3.905 for the class I group and lowest for the Class III cleft group (82.37 ± 8.281). Among the three study groups, class I had a significantly lower effective mandibular size (115.37 ± 5.669) compared to the class III without cleft group, which recorded the highest mean value of 124.74 ± 15.86 mm. Table 6 shows that there was no statistical significance among the groups with respect to the vertical position of the hyoid bone [HH1 ($p = 0.477$) and SH ($p=0.248$)] or the hyoid bone position from the cervical vertebra [C3H ($p =0.475$)]. However, the hyoid bone position with respect to retrognathion (HRGn) showed significant difference among the three groups. Mann-Whitney test for the HRGn showed a P value of 0.327 between Class I and Class III clefts and 0.009 between Class III cleft and Class III non-cleft groups, which were not significant. The Class III without cleft group has a significant difference compared to that of class I group ($P =0.002$) (Table 7).

DISCUSSION:

Resting above the tracheal rings in the midline, the hyoid bone maintains the airway patency. The morphology of the hyoid bone is likely to be shaped by the muscles and tendons which are attached to it and perform a variety of functions including maintenance of airway patency above the tracheal rings and mastication. Its position is strategic and influenced by structural changes and functional demands arising from its attachments. Over the course of evolution, the hyoid bone has migrated posteriorly and caudally[12]. Palato-epiglotic lockup, which is seen in early animals, allows them to swallow and breath simultaneously, this is due to non-projection of the hyoid into pharynx. Even in infants this palato-epiglotic lockup is seen up to 12 to 18 months of age, which clearly indicates the positional variations of hyoid bone in humans as an adaptation to the functional demands. Relocation of the hyo-laryngeal complex during the process of evolution and maturation of infantile stomatognathic functions is beneficial in promoting speech, but is disadvantageous in terms of forming a seal between the epiglottis and soft palate increasing the risk of aspiration.

During deglutition, harmony exists between the supra and infrahyoid muscles which to some extent is due to spatial relationship between the oral cavity, hyoid bone, epiglottis and the mandible. All of these functions are likely to be altered due to structural aberrations, such as an increase or decrease in the size of the jaws and orofacial clefts. Literature[13] shows that in atypical deglutition conditions, the hyoid is positioned more inferiorly, which is attributed to hypertonic infra-hyoid and hypotonic supra-hyoid musculature, resulting in altered tongue posture.

Skeletal class III is a condition clinically manifested as a prognathic mandible with increased prominence of the chin and a retrognathic maxilla manifested as a mid-facial deficiency. Both skeletal III and the Cleft conditions exhibit similar manifestations clinically as a concave profile, but their physiology is varied. Cleft subjects exhibit a concave profile chiefly due to retarded growth of the maxilla, which arises due to failure in fusion of maxillary segments. Due to the presence of cleft condition the stomotognathic functions performed by the lingual, palatal and pharyngeal muscles are disturbed leading to adaptive changes in the hyoid bone position. Maxillary location (SNA) is not associated with the reduction in upper airway whereas with the prognathism of the mandible the hyoid bone is observed to be located more anteriorly increasing the lower airway[2]. This is partly due to the attachments of the extrinsic muscles of the tongue to both the hyoid and the mandible. Hyoglossus is the muscle attaching the tongue to the hyoid bone acts to depress and retract the tongue when hyoid is stabilized by infrahyoid muscles. The genioglossus muscles act opposite to the hyoglossus, arising from the superior mental spines and inserting into the tongue. In subjects with skeletal class III and no evidence of cleft, the condition is related to genetic variants involving the growth of mandible while the subjects exhibiting skeletal class III with cleft, other genetic variants and iatrogenic factors are involved. Effective maxillary and mandibular lengths also show a relatively normal mandibular size in Skeletal Class III individuals with cleft compared to skeletal Class III subjects.

The hyoid bone descends gradually until adolescence relative to the cranial base, and a bit of additional descent is seen at puberty[14]. Adamidis and Spyropoulos[3] showed that in skeletal class III patients, the hyoid bone is positioned anteriorly due to morphological variation in the mandible compared to the skeletal class I pattern. Allhaja and Al-Khateeb[9] evaluated a weak but significantly forward-positioned hyoid bone in class III compared to Class II subjects with reference to 3rd cervical vertebrae. Kim et al[8] also showed a significantly anterior and inferior positioning of hyoid in class III & posterior-superior positioning in class II subjects. A similar positioning of the hyoid was demonstrated in cleft patients by Wolfram et al.[7] These studies show that the hyoid bone is subjected to a change in position owing to alterations in the anatomy of the associated structures. In contrast, Nidhin Philip Jose et al [15], Samare Mortazavi et al[16] found that class I, II, and III subjects with normal growth patterns maintained a relatively constant position with a significant degree of variation in the position of the hyoid bone in patients with different skeletal patterns. Maria Julia et al[17] summarized that hyoid bone position is stabilized owing to the functional alteration. With such contradictory evidence regarding the position of the hyoid bone and the paucity of literature regarding its position in cleft subjects, this study was conducted to evaluate the variation in the position of the hyoid bone in skeletal class III with and without clefts.

Eliana Dantas da Costa et al[18] form their study inferred a poor correlation in evaluating hyoid triangle with 3D CBCT, as the 3D rendered reconstruction might omit information embedded in CBCT Volume making linear measurements reliable but not accurate. Despite its shortcomings, lateral cephalogram has been proven by studies to be of good diagnostic value; hence, in this study, the hyoid position was evaluated from retrospectively collected lateral cephalograms, which is a routine diagnostic aid in orthodontics. Graber described cephalostat head position, spine posture, and functional variations as factors determining the hyoid bone position. Head Position is likely to be altered in patients who are mouth breathers; they exhibit a vertical growth pattern and tend to have extended neck posture, which positions the hyoid more anteriorly to decrease the lower pharyngeal airway. However Kim et al[8] and Sashi et al[19] showed that the hyoid bone position remains unchanged in various growth patterns (Normodivergent, Hypodivergent and Hyperdivergent). Maria Julia et al[17] also showed a similar finding in mouth breathing children where the hyoid bone position was stable and is not subjected to alterations with the changes in the respiratory pattern to maintain correct ratios in the airway.

The Chang-Min Sheng et al[14], showed minor variation in hyoid bone at puberty, to avoid the alteration in position based on the age in our study post-pubertal subjects were taken. Tsai HH17 showed no evidence of sexual dimorphism of hyoid bone in children. Skeletal class III malocclusion usually exhibits a prognathic mandible that has a strong genetic predisposition; it is also observed in cleft conditions that occur due to a hypoplastic maxilla rather than true mandibular prognathism. This difference in jaw size is evident in the current study wherein the effective mandibular length in the class III non-cleft group was 124.74± 15.86 mm which is significantly greater than that in the class III cleft (111.79 ± 8.88 mm) and class I groups (115.37 ± 5.66 mm). Class III with cleft group had significantly smaller effective maxillary length (82.37 ± 2.28 mm) than the other groups, which is clearly indicative of a deficiency arising from the cleft condition. Notably, the class III cleft group showed a significantly smaller effective mandibular length among the groups.

The hyoid bone is closely associated with the mandible and is subjected to positional changes synchronously with prognathism and retrognathism. In the current study, the hyoid bone was positioned more posteriorly in the class III non-cleft group, in contrast to Wolfram et al[7]. In addition, there was no significant difference in the vertical position of the hyoid bone among all groups, indicating that irrespective of the variations in the skeletal patterns, the hyoid position remained constant in the vertical plane of the pharyngeal space. Kim et al[8], Wahaj A et al[10] showed that hyoid is positioned inferiorly in Class III & Cleft subjects. The current study showed that the Class III without cleft group had the highest mean rank for vertical positioning, which was not statistically significant.

The location of the hyoid bone with respect to the posterior surface of the mandible (retrognathion) showed a significant posterior positioning in the class III non-cleft group, which is similar to that reported by Mortazavi et al[16] where the highest mean HRGn was noted in class III subjects, although it was statistically insignificant. There was no significant change in the lower pharyngeal space (C3H) between the Class III with and without cleft groups and Class I subjects, thus indicating that airway patency is maintained as a functional adaptation that might involve soft tissue adaptation apart from the hyoid position. Hence, evaluation of the hyoid bone position in a static relation might not adequately provide the required data, and it needs to be evaluated dynamically along with the soft tissue adaptations that occur during various functional movements.

The limitations of the current study include its retrospective design, small sample size, and lack of gender grouping. Even though lateral cephalograms were show to have a diagnostic quality equivalent to that of CBCT in evaluating the hyoid bone position, the inherent factors of magnification and superimposition errors in the lateral cephalogram might undermine the precision in measurements. Implication of the cranial base morphology in the cleft patients is a subject of controversy nevertheless further light needs to be shed even on the cranial base morphology as the hyoid also is attached to the cranial base by means of stylo-hyoid muscle.

CONCLUSIONS:

The following conclusions were made from the study:

1) Hyoid bone position didn't change significantly in skeletal class III subjects with cleft lip and palate
2) Hyoid bone is positioned posteriorly in class III subjects without cleft
3) Hyoid bone is positioned more posteriorly in class III subjects without cleft compared to subjects having cleft with class III
4) No significant changes were observed in the vertical position of the hyoid bone

Tables:

Table 1: Land marks and Measurements for the identification of Hyoid Bone Position

Landmarks:	
Point A	The most posterior point on the curve of the maxilla between the anterior nasal spine and supradentale
Point B	The point most posterior to a line from infradentale to pogonion on the anterior surface of the symphyseal outline of the mandible
N (Nasion)	most anterior point of the frontonasal suture
Co (Condylion)	The most posterosuperior point on the curvature of the average of the right and left outlines of the condylar head
H	The most superior and anterior point on the hyoid bone
H1	Foot point of a perpendicular line from RGn to C3
RGn	The most protrusive point of retrognathion
C3	The most anterior and inferior point of the third cervical vertebra
S	The midpoint of sella turcica
Measurements:	
ANB (Degrees)	Angle between point A and B at nasion
Co-Point A(mm)	Distance between Co to Point A
Co- Point B(mm)	Distance between Co to Point B
H-RGn (mm)	Distance between H and RGn
HH1(mm)	Distance between H and H1
C3H (mm)	Distance between C3 and H
SH (mm)	Distance between S and H

Table 2: Descriptive statistics for Effective length of Maxilla (Co- Point A) & Mandible (Co to Gn)

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean
						Lower Bound
Effective Maxillary Length (Co-PointA)	Class I	19	92.16	3.905	.896	90.28
	Class III Cleft	19	82.37	8.281	1.900	78.38
	Class III non cleft	19	89.79	6.762	1.551	86.53
	Total	57	88.11	7.704	1.020	86.06
Effective Mandibular Length (Co-Gn)	Class I	19	115.37	5.669	1.300	112.64
	Class III Cleft	19	111.79	8.886	2.038	107.51
	Class III non cleft	19	124.74	15.863	3.639	117.09
	Total	57	117.30	12.121	1.606	114.08

Table 3: Descriptive statistics of the hyoid bone position among the group

	N	Mean	Std. Deviation	Minimum	Maximum
HRGn	57	42.5263	7.18469	29.00	59.00
HH1	57	4.2632	3.78331	.00	20.00
C3H	57	35.4123	5.78261	23.00	52.00
SH	57	102.6228	12.05022	74.00	134.00
groups	57	2.0000	.82375	1.00	3.00

Table 4: Inferential Statistics comparing the effective lengths of Maxilla and Mandible by ANOVA test

		Sum of Squares	df	Mean Square	F	*P* value
Effective Maxillary Length (Co-PointA)	Between Groups	991.263	2	495.632	11.476	<.001
	Within Groups	2332.105	54	43.187		
	Total	3323.368	56			
Effective mandibular Length(Co-Gn)	Between Groups	1698.667	2	849.333	7.024	.002
	Within Groups	6529.263	54	120.912		
	Total	8227.930	56			

Table 5: Association of the maxillary and mandibular lengths between the groups by Tukey Post Hoc Test

Dependent Variable	(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	*P* Value	95% Confidence Interval	
						Lower Bound	Upper Bound
Effective Maxillary Length (Co-PointA)	Class I	Class III Cleft	9.789*	2.132	<.001	4.65	14.93
		Class III non cleft	2.368	2.132	.512	-2.77	7.51
	Class III Cleft	Class I	-9.789*	2.132	<.001	-14.93	-4.65
		Class III non cleft	-7.421*	2.132	.003	-12.56	-2.28
	Class III non cleft	Class I	-2.368	2.132	.512	-7.51	2.77
		Class III Cleft	7.421*	2.132	.003	2.28	12.56
Effective mandibular Length(Co- Gn)	Class I	Class III Cleft	3.579	3.568	.578	-5.02	12.18
		Class III non cleft	-9.368*	3.568	.030	-17.97	-.77
	Class III Cleft	Class I	-3.579	3.568	.578	-12.18	5.02
		Class III non cleft	-12.947*	3.568	.002	-21.55	-4.35
	Class III non cleft	Class I	9.368*	3.568	.030	.77	17.97
		Class III Cleft	12.947*	3.568	.002	4.35	21.55

Table 6: Krushkal-Wallis test evaluating the significant difference of parameters measuring the Hyoid bone position between groups

	HRGn	HH1	C3H	SH
Kruskal-Wallis H	11.690	1.479	1.488	2.787
df	2	2	2	2
P Value	.003	.477	.475	.248

Table 7: Mann-Whitney Test for HRGn among the groups

HRGn	Class I & Class III Cleft	Class III cleft & Class III non cleft	Class I & Class III non cleft
Mann-Whitney U	147.00	90.500	74.500
Wilcoxon W	337.00	280.500	264.500
Z	-0.980	-2.630	-3.100
P Value	0.327	0.009	0.002

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