The positional changes of hyoid bone in children

Hung-Huey Tsai*

The purpose of this study was to investigate the developmental changes of the hyoid bone position in children from deciduous dentition to early permanent dentition. There was no sexual dimorphism in hyoid bone positions. The growth of the structures around the hyoid bone began to decline from late mixed dentition stage. During growth, Go-H was almost equal to C3-H and the hyoid bone was located near and above the line that connected C3 and Me.

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INTRODUCTION

The hyoid bone, unlike all other bones of the head and neck, has no bony articulations. The anteroposterior position of the hyoid bone is determined by the conjoint action of the muscles that are attached to structures above and below it and the resistance provided by the elastic membranes of the larynx and the trachea.[1-3] There are two major groups of muscles, the suprahyoid and the infrahyoid, attaching to the hyoid bone. The suprahyoid muscles suspend the hyoid bone, the larynx, the pharynx, and the tongue. They rely on the hyoid bone for their actions and have certain very important functions. The digastric muscles increase the anteroposterior dimension and the oropharynx during deglutition, while the posterior belly of the digastric and the stylohyoid muscle act to prevent regurgitation of food after swallowing. The geniohyoid and mylohyoid muscles are attached at or near the symphysis of the mandible. The attachments of these muscles may affect the position of the hyoid bone by way of tongue movements and also through mandibular movements. Gross changes in tongue position can be assessed by analyzing changes of hyoid bone position. The suprahyoid muscles depress the mandible by contracting against a fixed hyoid platform, the absence of which may seriously impair mandibular opening.

Without the hyoid bone, our facility of maintaining an airway, swallowing and preventing regurgitation, and maintaining the upright postural position of the head could not be as well controlled. Therefore, careful supervision in developmental changes of hyoid position is important. Although Bench[4] found 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, cephalometric evaluation of hyoid bone position has been limited to a few studies that vary in both the methods and the characteristics of the sample.[1,5-7] The early detection of anomalies of hyoid bone position requires an understanding of the normal developmental changes. The purpose of this study was to analyze the positional changes of hyoid bone relative to the mandible and the third cervical vertebrae in normal children from deciduous dentition to early permanent dentition, on the basis of lateral cephalometric radiographic records.

MATERIALS AND METHODS

The materials were 221 lateral cephalometric radiographs, from deciduous dentition to early permanent dentition, collected by our department. The sample consisted of 109 boys and 112 girls. All subjects had natural dentitions and did not have craniofacial anomalies, syndromes, clefting, or symptoms or signs of dysfunction of the masticatory system. Standard lateral cephalometric radiographs of the children with the teeth in habitual occlusion and with the head oriented horizontally with the Frankfort (FH) plane were taken from the cephalostat in accordance with the standard cephalometric procedures. The materials were divided into four stages according to the dental age: deciduous dentition (stage 1), early mixed dentition (stage 2), late mixed dentition (stage 3), and early permanent dentition (stage 4).

The radiographs were traced by hand over an illuminated viewer onto acetate paper and appropriate cephalometric reference points were digitized (Figure 1)

* Hung-Huey Tsai, DDS, PhD., Department of Pedodontics, School of Dentistry, China Medical College, 91 Hsueh Shih Road, Taichung. 404 Taiwan.

Voice: 886-4-22055674
Fax: 886-4-22014043
E-mail: tasipopo@tcts.seed.net.tw

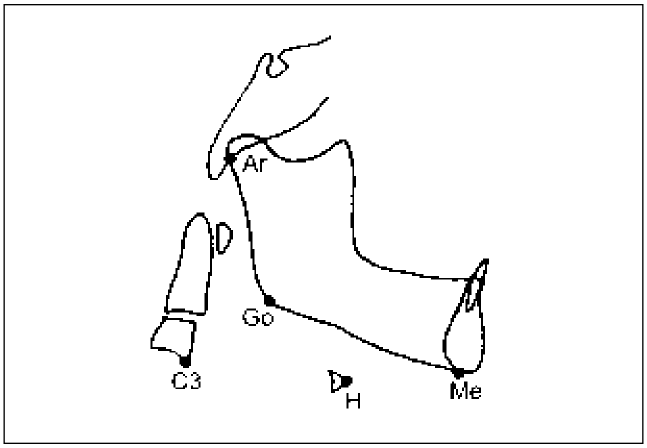

Figure 1. Cephalometric reference points used to identify hyoid bone measurements.

C3 (third vertebra): The most inferior and anterior point on the corpus of the third cervical vertebrae.
H (hyoidale): The most superior and anterior point on the body of the hyoid bone.
Me (menton): The most inferior point on the mandibular symphysis.
Go (gonion): The point where the lower border of the mandibular body meets the posterior border of the ramus.
Ar (articulare): The point of intersection of the posterior border of the condylar process and the inferior border of the occipital bone.

on a digitizer connected to a personal computer to construct five linear and six angular measurements describing the position of the mandibular, cervical, and hyoid structures (Figure 2). All tracings and digitization of the radiographs were carried out by the same person. The midlines of all the contours of bilateral structures were traced to minimize errors due to positioning, differential magnification, and/or symmetry.

All cephalometric landmarks were coordinated with the X- and Y-axes; the X-axis is the line parallel to the FH plane from reference point gonion (Go) and the Y-axis is the line perpendicular to the FH plane from reference point gonion (Go). Calculations were performed by means of the computerized cephalometric systems Winceph (version 4.0, Rise Co., Japan). Thirty-six lateral cephalometric radiographs, randomly selected, were traced twice to assess intraexaminer reliability. The differences between the means of the first and second tracings for each of the variables were tested by means of paired t-tests to evaluate the error of the method, which ranged from 0.36 mm to 0.88 mm for the linear measurements and from 0.48 to 1.52 for the angular measurements. All these were well within the acceptable range.

Statistical analysis was performed using the SigmaStat and SigmaPlot for Windows computer software. The data were analyzed with Student's t-test for sexual dimorphism in all measurements for each stage, and no significant differences were found. The level of significance was determined at $p < 0.05$. The sexes

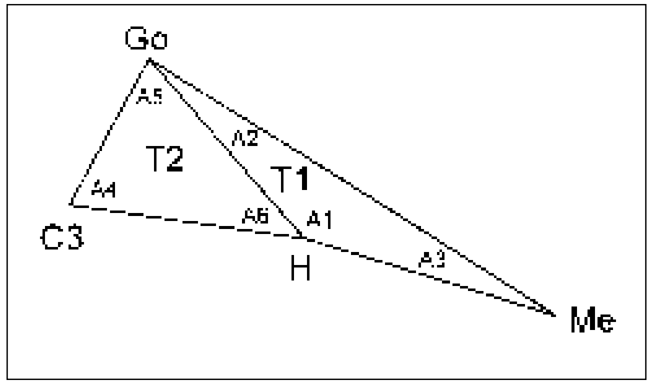

Figure 2. Linear and angular measurements

Linear measurements	Go-Me: The linear distance between Go and Me
	Go-H: The linear distance between Go and H
	Go-C3: The linear distance between Go and C3
	C3-H: The linear distance between C3 and H
	Me-H: The linear distance between Me and H
Angular measurements	A1: The angle formed by Go-H and Me-H
	A2: The angle formed by Go-H and Go-Me
	A3: The angle formed by Me-H and Go-Me
	A4: The angle formed by Go-C3 and C3-H
	A5: The angle formed by Go-C3 and Go-H
	A6: The angle formed by Go-H and C3-H

T1: The triangle formed by joining the reference points Go, Me, and H.
T2: The triangle formed by joining the reference points Go, C3, and H.

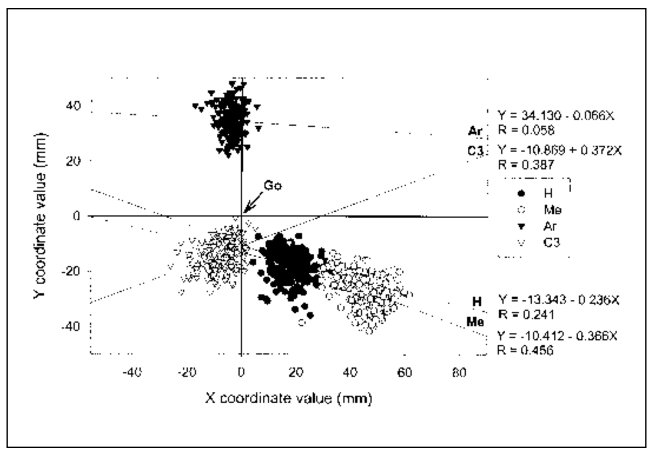

Figure 3. Actual Y-coordinate values of the reference points versus X-coordinate values.

were then pooled and mean values and standard deviations for the measurements were derived. Analysis of variance (anova) was used for comparison of mean values for each measurement among four stages. Regression analysis was used to determine the relationship between X- and Y-coordinate values of each reference point and the relationship between linear and angular measurements of T1 and T2 (Figure 2). Paired t-tests were employed, through all the stages, for comparisons between A2 and A3 and between Go-H and Me-H in T1, and between A4 and A5 and between Go-H and C3-H in T2. Multiple linear regression analysis was used to predict the position of the hyoid bone.

Table 1. Linear and angular measurements and their changes from stage 1 to 4 (T1).

Stage	Go-Me (mm) mean	Go-Me (mm) s.d	Go-Me (mm) anova	Go-H (mm) mean	Go-H (mm) s.d	Go-H (mm) anova	Me-H (mm) mean	Me-H (mm) s.d	Me-H (mm) anova
Stage 1 (N=42)	[illegible]	2.87		19.21	4.06		20.50	4.13	
Stage 2 (N=73)	48.51	4.24	*	22.80	4.31	*	26.83	4.53	*
Stage 3 (N=52)	52.44	4.14	*	25.70	4.98	*	31.70	5.67	*
Stage 4 (N=54)	58.90	4.12	n.s.	29.13	5.24	n.s.	32.84	5.22	n.s.

Stage	A1 (degree) mean	A1 (degree) s.d	A1 (degree) anova	A2 (degree) mean	A2 (degree) s.d	A2 (degree) anova	A3 (degree) mean	A3 (degree) s.d.	A3 (degree) anova
Stage 1 (N=42)	154.52	12.74		[illegible]	7.84		12.16	6.46	
Stage 2 (N=73)	150.50	14.05	n.s.	11.12	7.92	n.s.	9.35	6.66	n.s.
Stage 3 (N=52)	148.87	20.64	*	16.99	14.27	*	14.15	5.68	*
Stage 4 (N=54)	147.60	15.85	n.s.	17.46	14.27	n.s.	14.01	7.45	n.s.

* P<0.05

n.s not significant

Table 2. Linear and angular measurements and their changes from stage 1 to 4 (T2).

Stage	Go-C3 (mm) mean	Go-C3 (mm) s.d	Go-C3 (mm) anova	Go-H (mm) mean	Go-H (mm) s.d	Go-H (mm) anova	C3-H (mm) mean	C3-H (mm) s.d.	C3-H (mm) anova
Stage 1 (N=42)	[illegible]	[illegible]		19.21	4.06		20.91	3.12	
Stage 2 (N=73)	[illegible]	[illegible]	*	23.83	4.31	*	[illegible]	[illegible]	*
Stage 3 (N=52)	[illegible]	4.60	*	25.70	4.98	*	28.34	[illegible]	*
Stage 4 (N=54)	20.96	[illegible]	n.s	29.13	5.24	n.s	[illegible]	4.11	n.s.

Stage	A4 (degree) mean	A4 (degree) s.d.	A4 (degree) anova	A5 (degree) mean	A5 (degree) s.d	A5 (degree) anova	A6 (degree) mean	A6 (degree) s.d	A6 (degree) anova
Stage 1 (N=42)	68.18	[illegible]		[illegible]	24.29		29.31	15.25	
Stage 2 (N=73)	72.70	18.14	n.s.	73.67	15.92	n.s.	32.33	12.27	n.s.
Stage 3 (N=52)	[illegible]	18.45	n.s.	67.87	12.41	n.s.	39.67	[illegible]	*
Stage 4 (N=54)	70.75	19.20	n.s.	66.97	12.36	n.s.	42.02	14.15	n.s.

* P<0.05

n.s not significant

RESULTS

Figure 3 is a graph that the actual Y-coordinate values of the reference points are plotted against X-coordinate values. Figures 4 and 5 are graphs that the actual degree and distance of T1 are plotted against Go-Me distance. And Figures 6 and 7 are graphs with the actual degree and distance of T2 are plotted against Go-C3 distance. From the data points, the best-fit straight lines are drawn and the least regression equations of the form Y=A+B(X are determined.

Tables 1 and 2 show the mean values and the standard deviations of the measurements that exhibited differences among each stage. In all linear measurements, significant increases were seen from stage 1 to 2 and from stage 2 to 3, but no significant changes took place from stage 3 to 4. In angular measurements, A2, A3, A6 increased and A1 decreased significantly from stage 2 to 3.

The results of comparisons between A2 and A3 and between Go-H and Me-H in T1, and comparisons between A4 and A5 and between Go-H and C3-H in T2 are shown in Tables 3 and 4 respectively. There were significant differences between A2 and A3 and between Go-H and Me-H in T1. However, there were no significant differences between A4 and A5 and between Go-H and C3-H in T2.

The multiple linear regression study (Table 5) showed strong correlations between coordinate values of H and coordinate values of Me and C3. The position

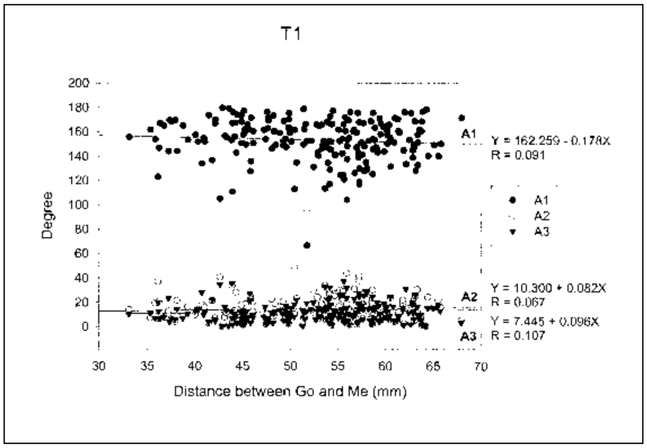

Figure 4. Actual degrees of A1, A2, and A3 versus Go-Me distance in T1.

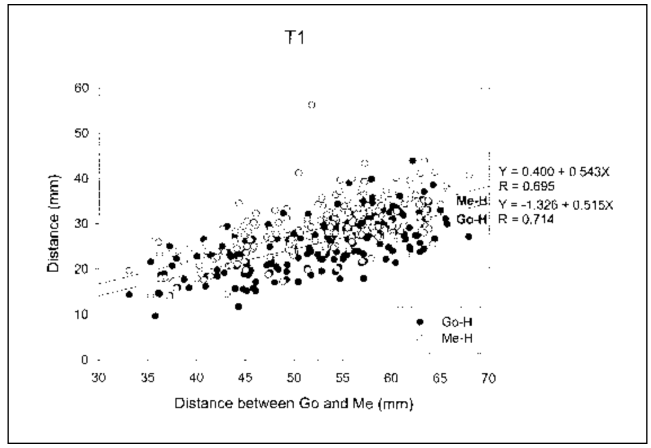

Figure 5. Actual distances of Me-H and Go-H versus Go-Me distance in T1.

Table 3. Comparisons between A2 and A3 and between Go-H and Me-H in T1.

T1	Measurements	mean	s.d.	Paired t-test
Angular measurements	A2	14.484	10.474	
	A3	12.358	7.648	P<0.001
Linear measurements	Go-H	25.064	6.152	
	Me-H	28.261	6.671	P<0.001

Table 4. Comparisons between A4 and A5 and between Go-H and C3-H in T2.

T1	Measurements	mean	s.d.	Paired t-test
Angular measurements	A2	14.484	10.474	
	A3	12.358	7.648	P<0.001
Linear measurements	Go-H	25.064	6.152	
	Me-H	28.261	6.671	P<0.001

of the hyoid bone can be predicted from the linear measurements Go-Me and Go-C3 and angular measurements A2 and A5 as well.

In order to make a summary of the results, the mean positions of the reference points and the lines that the reference points were connected with were transferred from the tracing of stage 1 (deciduous dentition) to stage 4 (early permanent) after superimposition on the X- and Y-axes (Figure 8).

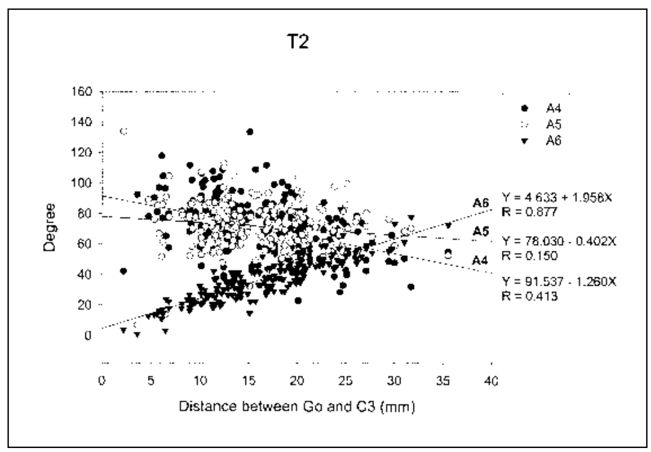

Figure 6. Actual degrees of A4, A5, and A6 versus Go-C3 distance in T2.

DISCUSSION

The position of the hyoid bone takes an active part in the cranial balance[2] and serves as a muscle junction and linkage element to the mandible without bony articulation. Fixation of the hyoid bone by the infrahyoid muscles allows the anterior suprahyoid muscles to pull the lower jaw toward the hyoid bone and open the mouth. As the hyoid bone is a very important element for the function of both the suprahyoid and infrahyoid groups of muscles, its role in contributing to a specific orientation and function of these muscles might be instrumental in the establishment of specific structural elements of the jaws and the occlusion of the teeth.

Studies on various population samples have shown that changes in hyoid bone position seem to be related to changes in mandibular position.[1,6,8-11] Also, the position of the hyoid bone has been studied in relation to head posture and was found to adapt to anteroposterior changes in head position.[2,12]

In this study, lateral cephalometric radiographs taken with the teeth in habitual occlusion and with the head oriented horizontally with the FH plane, the relations between the hyoid bone and the other reference points were shown by X- and Y-coordinate values first, and then the relations between the hyoid bone and the mandible body and the relations between the hyoid bone and the third cervical vertebrae were shown by triangles T1 and T2 respectively.

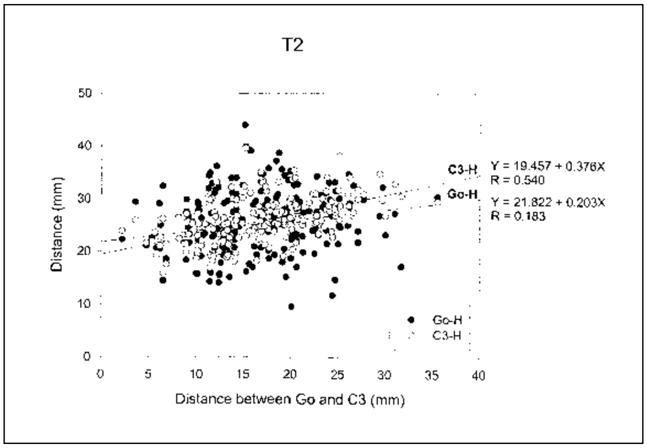

Figure 7. Actual distances of C3-H and Go-H versus Go-C3 distance in T2.

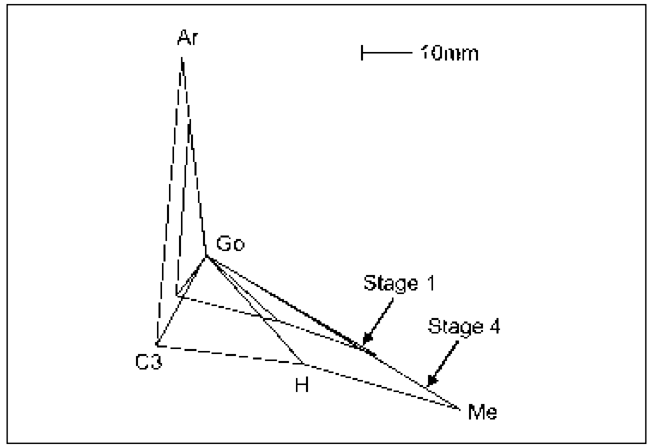

Figure 8. Superimposition of mean positions of the reference points in stage 1 and stage 4.

Table 5. Multiple linear regression analysis.

Stage	Go-C3 (mm)			Go-H (mm)			C3-H (mm)			A4 (degree)			A5 (degree)			A6 (degree)		
	mean	s.d.	anova	mean	s.d.	anova	mean	s.d.	anova	mean	s.d.	anova	mean	s.d.	anova	mean	s.d.	anova
Stage 1 (N=42)	[illegible]	[illegible]		19.21	4.66		20.91	2.12		68.18	21.98		[illegible]	24.29		29.31	15.25	
			*			*			*			n.s.			n.s.			n.s.
Stage 2 (N=73)	[illegible]	[illegible]		23.63	4.31		24.25	2.57		72.70	18.14		73.67	15.92		[illegible]	[illegible]	
			*			*			*			n.s.			n.s.			*
Stage 3 (N=52)	[illegible]	4.60		25.70	4.98		25.34	[illegible]		73.06	18.45		67.87	12.41		[illegible]	[illegible]	
			n.s.			n.s.			n.s.			n.s.			n.s.			n.s.
Stage 4 (N=54)	20.96	[illegible]		29.13	3.24		[illegible]	4.11		70.75	19.20		[illegible]	[illegible]		43.02	14.15	

R: correlation coefficiane, HX: X-coordinate value of H, HY: Y-coordinate value of H, MeX: X-coordinate value of Me, MeY: Y-coordinate value of Me, C3X: X-coordinate value of C3, C3Y: Y-coordinate value of C3

It was found that the reference points C3, Me, and H were in intimate relations with the reference point Go (Figure 3), suggesting that it was suitable to move Go to the origin of the coordinate. C3 moved downward and backward and Me and H moved downward and forward relative to Go during growth.

When T1 is shown with a triangle, the mandibular body (Go-Me) is the triangular base and hyoid bone (H) is the triangular apex. When T2 is shown with a triangle, the distance between gonion and hyoid bone (Go-H) is the triangular base and hyoid bone (H) is the triangular apex. A2 was greater than A3 and Me-H was greater than Go-H, both by almost same quantity, through all the stages in T1 (Figures 4 and 5, Tables 1 and 3).

On the other hand, A4 was almost equal to A5 and Go-H was almost equal to C3-H, and A6 increased though A4 and A5 decreased, through all the stages in T2 (Figures 6 and 7, Tables 2 and 4). It is suggested that T2 is an isosceles triangle that changes its shape and T1 is a triangle that changes a little during growth. This suggestion can be judged to be right by Figure 8. It was also found that the hyoid bone was located near and above the line which C3 and Me were connected. This might indicate that the vertical growth behavior of the hyoid bone closely paralleled that of the vertebral bodies and the mandibular bodies.

During growth, a relatively stable superoinferior hyoid position was maintained, and it descended together with the mandible and the cervical vertebrae. From Tables 1 and 2, it was found that significant increases were not seen with all linear measurements from stage 3. This might indicate that the growth of the structures around the hyoid bone began to decline from late mixed dentition stage.

It is generally known that the hyoid bone is positioned at a level opposite the lower portion of the third cervical vertebrae and the upper portion of the fourth cervical vertebrae.[3] Since the hyoid bone can not be sometimes seen clearly on the radiographs, multiple linear regression analysis was carried out (Table 5) in order to know whether the accurate position of the hyoid bone could be predicted by the position of the mandible and the cervical vertebrae in growing children.

It was found that the position of the hyoid bone could be predicted if we know the position of the Me and C3 in the coordinate or know the distance Go-Me and Go-C3 and the angle formed by Go-Me and Go-C3 (A5+A2). There are four kinds of combinations of the distance and the angle, Go-H and A5, Go-H and A2, Me-H and A3, and C3-H and A4, to predict the position of the hyoid bone. It was the most certain by using Go-H (R=0.828) and A5 (R=0.892) to predict the position of the hyoid bone, next by C3-H (R=0.786) and A4 (R=0.855). This might indicate that the hyoid position in relation to the cervical vertebrae and the mandibular angle showed little variability in growing children.

CONCLUSION

The aim of this study was to contribute to our understanding of the positional changes of the hyoid bone in children. There was no sexual dimorphism in hyoid bone positions. There was a relative constancy of hyoid bone position throughout growth periods. The relations of the hyoid bone position were stable when referred to the third cervical vertebrae and the mandibular body. The position of the hyoid bone could be predicted by using the position of Me and C3 relative to Go or by using the distance Go-Me and Go-C3 and the angle formed by Go-Me and Go-C3.

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