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Predictive Value of Radiographic Analysis of Menton, Hyoid Bone, and the Third Cervical Vertebra Angle

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Abstract

PREDICTIVE VALUE OF RADIOGRAPHIC ANALYSIS OF MENTON, HYOID BONE, AND THE THIRD CERVICAL VERTEBRA ANGLE

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The purpose of this study is to determine if the hyoid bone could be used as a reliable and stable reference landmark. Previous researchers have used cranial landmarks to determine the hyoid bone position. The results of these studies have shown a large variability in hyoid position. To determine the hyoid bone position, an analysis called the hyoid triangle was used. The hyoid triangle is formed by joining the cephalometric points retrognathion (the most inferior posterior point on the mandibular symphysis), hyoidale (the most superior anterior point on the body of the hyoid bone), and C3 (the most anterior inferior point on the third cervical vertebra). The hyoid triangle was constructed using landmarks that are closer to the axis of rotation of the head than the cranium. This decreases the effect of head movement on hyoid position. Thirty pretreatment orthodontic patients ranging in age from 9-15 were used. The sample was selected randomly, and included males, females, and was not limited to any particular

malocclusion type. Each patient had 2 lateral cephalometric films taken, with a mechanical holding device, to stabilize head position. Hyoid bone position was compared between the two radiographs. The results showed inconclusive evidence to validate the hyoid triangle as a method to locate the position of the hyoid bone.

LOMA LINDA UNIVERSITY

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Each person whose signature appears below certifies that this thesis in his opinion is adequate, in scope and quality, as a thesis for the degree Master of Science.

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CHAPTER 1

Introduction

The hyoid bone is unusual in that it has no bony articulations, and is supported entirely by muscles, ligaments, and fascia. For this reason in the past, the hyoid bone was not used as a cephalometric landmark. There are two major groups of muscles that attach to the hyoid bone; the suprahyoids and the infrahyoids. These muscles depend on this bone for carrying out their actions and important functions. During swallowing, the anteroposterior dimension of the oral pharynx increases, due to the action of the anterior belly of the digastric muscle. The posterior belly of the digastric, along with the stylohyoid muscle, prevents requrgitation of food after swallowing. The hyoid bone also serves as a fixed platform for the suprahyoid muscles to depress the mandible.

This bone also has many important functions that deal directly with the tongue; in fact, it has been called the skeleton of the tongue.[15] Since this is so, it may be possible that an adverse position of the hyoid bone could affect the occurance of tongue thrust.

Brodie[4] describes a chain of muscles encircling the head from front to back. The hyoid bone is linked to the suprahyoid and infrahyoid muscles. When these muscles are flexed, the head is tilted down. When they are relaxed, the head can be tilted back. When these muscles are in balance with the posterior muscles, the head is balanced on the vertebral column.

The contribution that the hyoid bone makes to the postural position of the head, the function of swallowing, and the position of the tongue, allows for the maintainance of the airway.

From this one can see that the hyoid bone is important in head posture, swallowing, tongue position, and in airway maintainance.

If the hyoid bone can be found to be a stable reference landmark, it could provide more information concerning: 1)tongue thrust, and 2)posture of the cervical vertebrae, which may help in the correction of the cause of some types of headaches.

CHAPTER 2

Review of the Literature

The validity of the measurement of the hyoid bone position has been very difficult to establish. Stepovich[18] reported that the position of the hyoid could not be duplicated in successive roentgenograms of the same person, no matter how short the time between sittings. King[11] described changes in the position of the hyoid due to changes in head position. He found that when the head is tipped backward the hyoid moves back. When the head is tipped forward the hyoid moves forward. Wood[19] found that when the head is in dorsiflexion the hyoid is elevated, and when the head is in ventriflexion the hyoid is directed downward. Graber[8] stated that although cephalometric analysis has been the preferred research technique, slight variations in head position in the cephalostat, postural position of the spine, and the state of function(rest, swallow) have significant effects on hyoid position. However, he does point out, that within these limitations it is possible to make some definite conclusions concerning the normal position of the hyoid bone. Thompson[17] found that as the mandible moves downward in mouth opening the hyoid bone tends to remain at a constant level, moving slightly backward. Grant[9] studied the position of the hyoid bone in

Class I, II, and III malocclusions. He concludes that the hyoid bone position is constant in all three classes, and that the position of the hyoid bone is determined by the musculature, and not by the occlusion of the teeth. Sloan[16] found lower and more posterior hyoid locations in Class I malocclusions; and higher and more forward hyoid postures in Class II malocclusions. He also found two distinct hyoid movement patterns during deglutition: 1)Cyclic pattern of hyoid movement typified as smooth and coordinated, 2)Elliptical pattern of hyoid movement typified by erratic, discoordinated behavior associated with tooth apart swallowing. Cuzzo and Bowman[5,7] found that changing tongue position with a tongue crib brought about a significant posterior and inferior repositioning of the hyoid, if the hyoid was located near the mandibular plane. If the hyoid was distant from the mandibular plane, change in tongue position did not effect a posterior and inferior shifting of the hyoid.

Durzo and Brodie[6] found the hyoid bone to be suspended by three sets of muscles--from the base of the cranium to the hyoid bilaterally, and from the symphysis of the mandible to the hyoid. It is the relative lengths of these sets of muscles which determine the anteroposterior relation of the hyoid to the vertebral column. In the vertical dimension, the hyoid occupies a fairly constant position;

opposite the lower portion of the body of the third, and the upper portion of the body of the fourth cervical vertebrae. Bench[1] studied a sample of 165 subjects from ages 2-45 years of age. He 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 vertebra (at age 3), to a position opposite the fourth cervical vertebra (at adulthood). King[11] states that the distance between the hyoid bone and the cervical vertebrae is constant until puberty, when the hyoid moves slightly forward.

Thus we see that some previous investigators have found that the hyoid bone has a variable position, from person to person and even from minute to minute in the same person.[8,18] Other investigators found positive correlations between hyoid bone position and skeletal type;[10,12,16,] while still others find no correlation at all.[5,7,9]

Most of the previous analyses have used cranial landmarks to determine hyoid postion. Since these cranial structures are located away from the hyoid bone, any variation in the cranial points would cause a seemingly large variation in the hyoid bone position, whether it moved or not.

To minimize the effect of head posture, Bibby[2] proposed an analysis model known as the hyoid triangle. The triangle is formed by joining the cephalometric points retrognathion (the most inferior posterior point on the mandibular symphysis), hyoidale (the most superior anterior point of the body of the hyoid bone), and C3 (the most inferior anterior position of the third cervical vertebra). Bibby[3] also attempted to associate mouth breathing and tongue thrust with hyoid bone position, but was unable to show any correlation. Rocabado[14] suggests using this triangle to determine hyoid position and from this determine normal and abnormal curvatures of the spine as well as normal and abnormal craniocervical relationships.

The objective of this study is to determine if the hyoid triangle measurements, that are proposed by Bibby[2] are repeatable on successive cephalometric films, using the same person.

CHAPTER 3

Methods and Materials

Thirty randomly selected patients from the Loma Linda University School of Dentistry Graduate Orthodontics Department were used. The patients were selected by using the first thirty consecutive patients that had their T1 radiographs taken. The radiographs were taken by the Radiographic Department of Loma Linda University School of Dentistry. The x-ray unit was a Quint Sectograph that consisted of a cephalostat to hold the patient, an anode positioned at the standard 60 inches from the patients midsagittal plane, and a film cassette fitted with intensifying screens. The patients selected were part of the new patients for the graduate orthodontic class beginning in June 1984. They ranged in age from nine to fifteen years old. Each patient had two lateral cephalometric films taken instead of one. The patients were placed in a mechanical holding device in a sitting position in an erect posture. This device, Fig. 1,2 allowed the patients to be placed in a repeatable position for the two lateral cephalometric films. The device was comprised of a backrest that measured 1.5 x 2.0 feet, a U-shaped extension arm, and a chest piece. Two straps were used to attach the backrest to the chair of the cephalometric unit. The

Fig. 1

Mechanical Holding Device

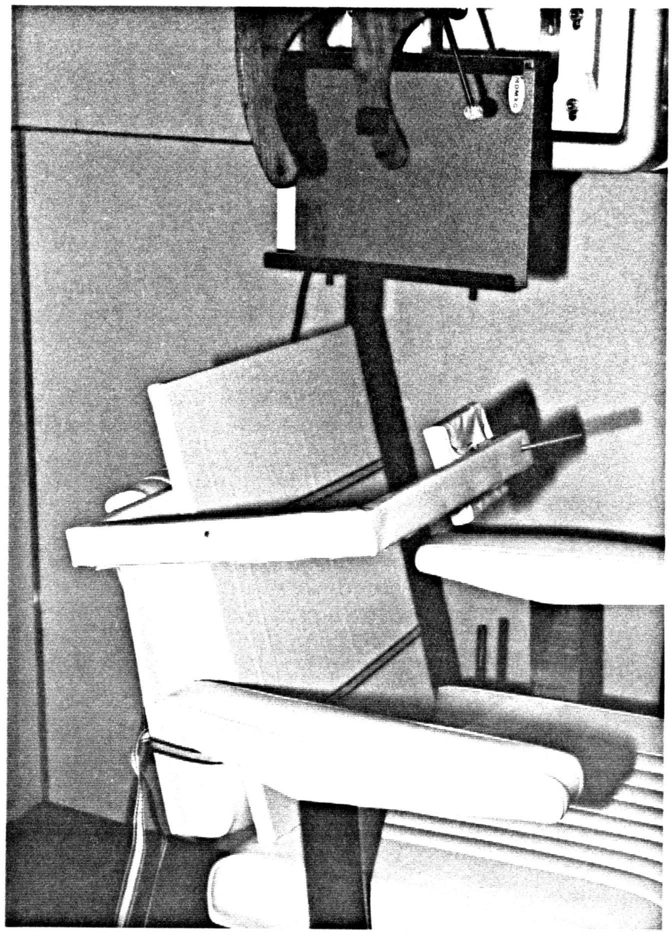


Fig. 2

Mechanical Holding Device with Patient

patient's back was positioned against the backrest in an erect posture. The extension arm was then placed to the right side of the patient and slid into position in the backrest. The chest piece was then inserted through the extension arm by means of a 1/4 inch steel bolt. The chest piece was positioned firmly against the chest of the patient and locked into position using a wing nut. This allowed the chest piece to be adjusted for different patient size. When the patient was placed in this device the upper body could not lean forward or backward. The cephalostat was then placed in the external auditory meatus and locked into position. A millimeter ruler was attached to the cephalostat in the center of mechanical porion. A straight edge was then used to line up a mark 15mm above the center of mechanical porion and the canthus of the eye, which will give you an estimate of Frankfort Horizontal. The head was adjusted so this line was parallel to the floor. A nose rod was placed against the bridge of the nose and tightened to hold this position. From this point on, the patient could not turn his head left or right, or tip his head backward or forward. The patient was then instructed to say the letter N and close his teeth and lips together to position the tongue in a repeatable position. The letter N was selected since it can be said with the teeth together, and because it is a long sounding letter. This also eliminated the possibility of swallowing during the film exposure. The first lateral cephalometric film was then taken. The patient was removed from the cephalostat and holding device, and then immediately following this a second cephalometric film was taken following the same method as described.

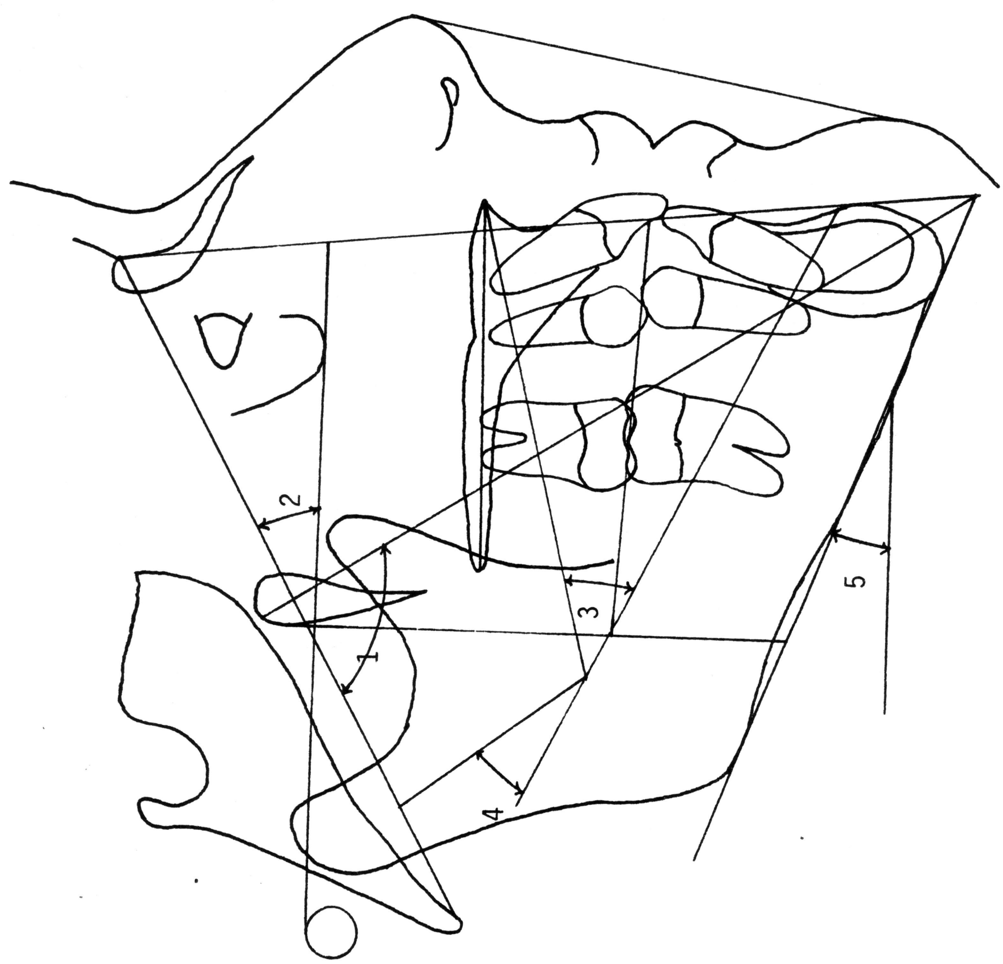
These two cephalometric films were traced by the same person, on acetate paper using an illuminated viewer. Measurements were taken to the nearest .5mm and .5 degree. A standard Ricketts analysis[13] was done on each of the thirty patients. (Fig. 3) Using these five measurements: 1)facial axis, 2)cranial deflection, 3)lower face height, 4)mandibular arc, and 5)mandibular plane, the patients facial type was determined. The three facial types are: 1)Dolichofacial, 2)Mesofacial, and 3)Brachyfacial. The thirty patients were grouped into these three categories according to their facial type.(Table 3) These three categories were used to determine what effects, if any, facial type has upon the hyoid triangle measurements.

Using the hyoid triangle, eight measurements were made to compare each of the thirty patients' first cephalometric film with the second cephalometric film, to determine if the hyoid position remains the same on both films. Listed below are the cephalometric landmarks used to derive the eight measurements comprising the hyoid triangle analysis proposed by Bibby and Rocabado.[2,14]

Fig. 3

Five Determinants of Facial Type

1) Facial Axis
2) Cranial Deflection
3) Lower Face Height
4) Mandibular Arc
5) Mandibular Plane



Definitions of Cephalometric Points and Planes: (Fig. 3)

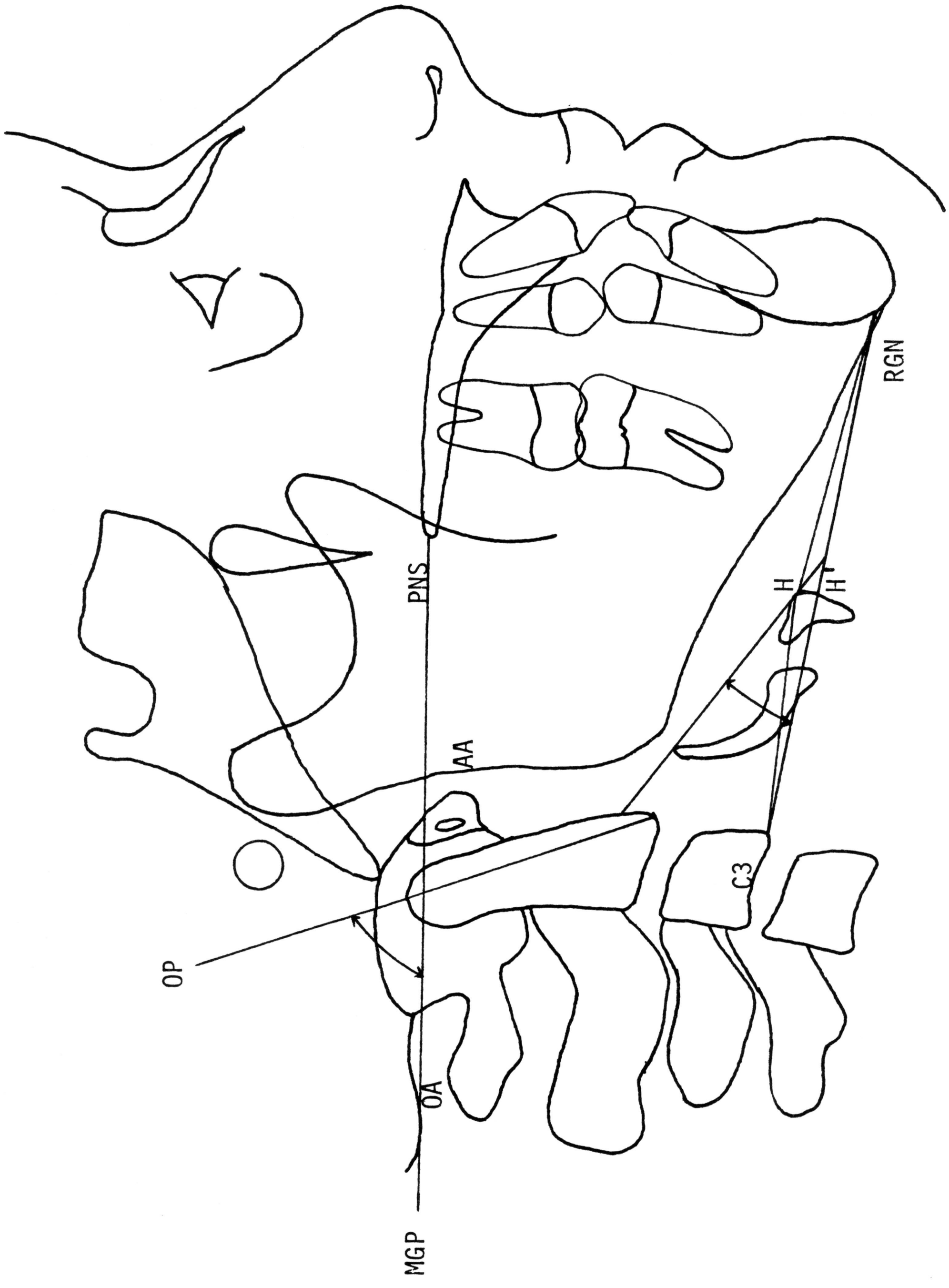
1. C3-The point at the most inferior anterior position of the third cervical vertebra.
2. RGn (retrognathion)-The most inferior posterior point on the mandibular symphysis.
3. H (hyoidale)-The most superior, anterior point on the body of the hyoid bone.
4. Hyoid plane-The plane from H along the long axis of the greater horns of the hyoid bone.
5. Hyoid plane angle-The most superior posterior angle made by the intersection of the hyoid plane with the plane of C3-RGn.
6. AA-The most anterior point of the body of the atlas (C1 vertebra) seen in the lateral cephalometric radiograph.
7. PNS (Posterior Nasal Spine)-The tip of the posterior nasal spine seen in the lateral cephalometric radiograph.
8. MGP (McGregor's Plane)-A line that connects the basi-occiput with the posterior nasal spine.
9. OP (Odontoid Plane)-A line that crosses from the anterior inferior angle of the odontoid to the apex of the odontoid.
10. OA-The distance from the basi-occiput to the posterior arch of the atlas (C1 vertebra).

The hyoid triangle is formed by connecting the points C3, RGn, and H. (Fig. 4) Millimeter measurements are taken of each of the three sides. A perpendicular line is drawn from H to C3-RGn and measured in millimeters. The distance from the basi-occiput to the posterior arch of the atlas is measured in millimeters. The distance from AA to PNS is measured in millimeters. The last two measurements are angles which are measured in degrees. The first is the angle that MGP makes with OP. The last is the angle that the hyoid plane makes with C3-RGn.

The data for determination of facial type and the eight hyoid triangle measurements were compiled into a table. (Appendix A,B,C) The statistical analysis done were: 1)t-test, 2)Scattergram, 3)Correlation, 4)ANOVA, 5)Regression Analysis, and 6)One Way ANOVA.

Fig. 4

Hyoid Triangle



CHAPTER 4

Results

All the data obtained from the acetate tracings were then compiled and statistically analyzed. The results from the t-test showed no significant difference between the first and second radiographs in the eight measurements, except for the angle formed by MGP and OP, in which there was a significant difference. (Table 1) This could be caused by a change in head position. It is interesting to note that all values show a high value of correlation. (Table 2)

Scattergrams were done on each of the eight measurements, and again each shows a high degree of correlation. The statistical test using ANOVA was used to determine if facial type Table 3, affected any of the eight measurements of the hyoid triangle. The results obtained were varied. (Table 4) In this table the three facial types were placed into two subsets according to their effect on the hyoid measurements. There was no pattern in the relative effects of the facial type on the hyoid measurements. For the hyoid measurements C3-RGn, H-H', Hyoid P.A., and OA, all three facial types were placed in the same subset indicating the three facial types had the same effect on these hyoid measurements. For the hyoid measurement C3-RGn, group 3(dolichofacial) affected this measurement differently than group 1(brachyfacial) since they were each placed in different subsets. Group 2(mesofacial) appeared in both subsets, which means it had a range of values that affects C3-RGn similar to group 1(brachyfacial) and the other similar to group 3(dolichofacial). This table does not show what the effects on the hyoid triangle are, but it does show that facial type has an effect on the hyoid triangle measurements. In Table 5 only three hyoid measurements 1)C3-RGn, 2)H-RGn, and 3)AA-PNS were significantly affected by facial type. This again does not show what the effects of facial type were, only that they were significantly affected.

The position of the hyoid bone relative to the cervical vertebrae is listed in. (Table 6) These values with the standard deviations give a rough estimate of the normal values of the hyoid triangle measurements.

Table 2

Correlation Values*

Hyoid Triangle Measurements	Correlation
C3-RGn	0.985
C3-H	0.966
H-RGn	0.969
H-H'	0.902
Hyoid P.A.	0.850
AA-PNS	0.938
OA	0.956
MGP-OP Angle	0.988

*Correlation values between the first and second radiograph.
Note: A correlation value of 1.0 means the two values are equal.

Table 3

Facial Type

Group	Number of Patients	Facial Type
1	8	Brachyfacial
2	12	Mesofacial
3	10	Dolichofacial

Table 4

ANOVA*

Hyoid Triangle Measurement	Subset 1	Subset 2
C3-RGn	Group 2,3	Group 1,2
C3-H	Group 1,2,3	
H-RGn	Group 3	Group 1,2
H-H'	Group 1,2,3	
Hyoid P.A.	Group 1,2,3	
AA-PNS	Group 2,3	Group 1,3
OA	Group 1,2,3	
MGP-OP Angle	Group 1,3	Group 2,3

*Groups facial type according to its effect upon the hyoid triangle measurements.
Group 1=Brachyfacial
Group 2=Mesofacial
Group 3=Dolichofacial

Table 5

Affects of Facial Type

Hyoid Triangle Measurement	F Prob.*
C3-RGn	0.0499**
C3-H	0.2668
H-RGn	0.0024**
H-H'	0.2464
Hyoid P.A.	0.1144
AA-PNS	0.0497**
OA	0.9119
MGP-OP Angle	0.0859

*The F probability is the total cumulative value of the effects of the facial type on the hyoid triangle measurments.
**Significant values.

Table 6

Hyoid Triangle Norms*

Hyoid Triangle Measurement	Mean	Standard Deviation
C3-RGn	70.3666	9.390
C3-H	35.4667	4.392
H-RGn	35.6500	8.490
H-H'	-1.5333	4.796
Hyoid P.A.	17.3750	8.977
AA-PNS	36.8666	5.159
OA	7.6750	2.569
MGP-OP Angle	74.9750	10.016

*MGP-OP angle and Hyoid P.A. are in degrees, all other values are in millimeters.

Regression Analysis was done to measure if any one of the five determinants of facial type affects the hyoid triangle measurements. The results showed some of the five determinants of facial type to have significant affects and others to have no significant effect. In Table 7 the factor that affected the individual hyoid measurement the most are listed. No one individual determinant of facial type emerged as the single most important factor influencing all the hyoid measurements. All the hyoid measurements have listed a determinant of facial type that was the most dominant influence over all the other five determinants of facial type. The only hyoid measurements that were significantly affected by the individual facial type were: 1)C3-RGn, 2)H-RGn, 3)H-H', and 4)MGP-OP angle. The other four hyoid measurements were not significantly affected.

There is however a significant correlation between facial type and the hyoid measurements. In order to have this significant correlation, all five indicators of facial type must be used together. (Table 8) This table shows the cumulative correlation values using all five of the determinants of facial type, instead of individually as in Table 7.

Using the One Way ANOVA the coefficient of variation between the first and second radiograph was determined. The hyoid triangle values H-H' and Hyoid Plane Angle showed the most variation. (Table 9) Both of these values are a measure of the vertical position of the hyoid bone, which appears to be the least reproducable measurement. This would indicate that the majority of the hyoid triangle measurements are reproducable between the two radiographs, except for H-H' and Hyoid Plane Angle.

Table 7

Correlation Between Facial Type and Hyoid Triangle*

Hyoid Triangle Measurement	Facial Type Determinant	p Value
C3-RGn	Facial Axis	p<.025
C3-H	Lower Face H.	NS *
H-RGn	Lower Face H.	p<.005
H-H'	Mand. Plane	p<.05
Hyoid P.A.	Cranial Base D.	NS *
AA-PNS	Facial Axis	NS *
OA	Mand. Arc	NS *
MGP-OA Angle	Facial Axis	p<.01

*Lists the determinant of facial type that most significantly influences the individual hyoid triangle measurement.

Table 8

Cumulative Correlation (r) Values of Facial Type*

Hyoid Triangle Measurement	r
C3-RGn	.52
C3-H	.40
H-RGn	.60
H-H'	.47
Hyoid P.A.	.46
AA-PNS	.52
OA	.41
MGP-OP Angle	.60

*Lists the total cumulative correlation values of all five determinants of facial type.
Note: All r values have significant correlation.

Table 9

Coefficient of Variation*

Hyoid Triangle Measurement	Grand Mean	Standard Deviation	Coefficient of Variation
C3-RGn	70.3667	1.1583	1.65%
C3-H	35.4667	0.8165	2.30%
H-RGn	35.6500	1.5166	4.25%
H-H'	-1.5333	1.5111	98.56%
Hyoid P.A.	17.3750	3.4260	19.72%
AA-PNS	36.8667	1.2942	3.51%
OA	7.6750	0.5590	7.28%
MGP-OP Angle	74.9750	1.1673	1.56%

*Lists the amount of variation between the first and second radiographs for each of the hyoid triangle measurements along with the standard deviation.
Note: MGP-OP angle and Hyoid P.A. are in degrees, all other values are in millimeters.

CHAPTER 5

Discussion

In Table 1, the MGP-OP angle was the only one to be significantly different in the hyoid measurements. Table 6, showed MGP-OP angle to have the largest standard deviation. This angle is a measure of the head balancing on the cervical vertebrae. In looking at the data in Appendix A and B, nine patients had greater than 1 degree differences in the MGP-OP angle. This was probably caused by the patient's head not being positioned in exactly the same position in the first and second radiograph. Any change in head position will significantly affect all the measurements of the hyoid triangle. There was a wide variation observed in the H-H' measurement, as much as 6 millimeters difference between the first and second radiograph. In Table 9 the hyoid measurement H-H' showed a 98.56% variation between the grand mean and the standard deviation. It was suspected that this change was probably caused by the different head position noted in the MGP-OP angle. To test for this, the correlation of change in MGP-OP to the change in H-H' was studied using scattergrams. Nine subjects who had MGP-OP values greater than 1 degree were removed from the test, since it was assumed these had gross discrepancies in head position. The results of this test showed only a 0.147

correlation between MGP-OP and H-H', and only a 2% effect on the variability of H-H' by a change in MGP-OP angle. This indicates that changes in head position do not affect the H-H' measurement as was suspected.

In the planning stages of this thesis every attempt was made to be as thorough as possible to control as many of the variables, which would allow a repeatable position for the hyoid bone.

This has been a pilot study to test the validity of the eight hyoid triangle measurements proposed by Bibby[2] and Rocabado[14]. The information gathered from this study and the suggestions noted below could be used to improve on a later study to more accurately assess the value of the hyoid triangle measurements.

The x-rays taken on the thirty patients used in this study were taken by three different technicians, although they were instructed in the procedure by the author. To improve the repeatability of the head, body, and hyoid position, the x-rays should have been taken by one person. This would have minimized any error in head positioning caused by several different people taking the x-rays.

This study used the mechanical holding device on all thirty patients, and did not have a control group to evaluate the effectiveness of the mechanical holding device. There is the possibility that there is no difference in hyoid position when using or not using the mechanical holding device. An improvement to this study would be to have a control group of thirty patients with two lateral cephalometric films taken without the use of the procedure described in this thesis. These two groups could be compared to evaluate the effectiveness of the mechanical holding device.

One of the other areas where error may have been introduced in the study was when the patient was removed from the holding device after the first x-ray, and then replaced again in the device. To exactly duplicate the head position from the estimated Frankfort Horizontal was not possible. To avoid this the patient could have been left in the holding device and a waiting period of between 15 to 30 seconds lapsed before the second x-ray was taken. A second approach to this problem would have been to attach a marking device to the unit that would record the exact chin position after Frankfort Horizontal was obtained and the first x-ray taken. When the patient was replaced in the unit for the second radiograph this marker could be used to position the chin in the same position as when the first radiograph was taken.

The hyoid bone is strongly influenced by the position of the tongue. To control this, the patient was instructed to say the letter N which positioned the tongue in a repeatable position. Even with this procedure, there is the possibility that the patient may have been swallowing while either the first or second radiograph was being taken. This would cause the hyoid bone to be in a different position in the first and second radiograph. To help this situation, a practice session of several minutes could have been used to familiarize the patient with the procedure.

The patients used in this study ranged in age from nine to fifteen years old. During this period active growth is occurring, which could affect the relative position of the hyoid bone. A more accurate method would have been to conduct the study on non-growing patients where growth could not account for any change in the position of the hyoid bone. Another factor to consider is the time factor between the first and second radiographs. The interval of time between the two x-rays was less than five minutes. This leaves the possibility that the hyoid bone position may not be stable over long periods of time. To test for this, another x-ray could be taken six months to a year later and compared to the original set of x-rays. As mentioned earlier the thirty patients used in this study were going to be treated orthodontically. This orthodontic treatment could affect the position of the hyoid bone. So if this group had x-rays taken six months to one year later, any changes in hyoid position could have been due to: 1)growth, 2)orthodontic treatment, 3)the time factor, or 4)all three of these factors.

Further research should also be done concerning the curvature of the cervical vertebrae and its possible effect on hyoid position, and on certain types of migraine headaches; as has been suggested by Rocabado.[14] Since Dr. Rocabado's primary interest is in physical therapy, his main application of the hyoid triangle has been oriented more towards physical medicine than orthodontics. But these two areas could be combined. A lateral cephalometric film along with a lateral body film showing the curvature of the cervical vertebrae, could be taken. The two films could be compared to see if a correlation exists between the curvature of the cervical vertebrae, the hyoid triangle, and the possible cause of migraine headaches.

The most important factor to note when using the hyoid triangle is the high variability in the measurements. When using the method described in this paper, there still was a high variability. From this study, the reproducibility of the hyoid bones position using the hyoid triangle, is not reproducible. Unless further refinements of maintaining head, body, and tongue position are made, the hyoid triangle using this method, will not yield reproducible results.

CHAPTER 6

Conclusions

1. This study did not provide conclusive evidence to validate the hyoid triangle as a method to locate the position of the hyoid bone.
2. The effect of head posture strongly influences the measurements of the hyoid triangle which differs from Bibby's[2] findings.
3. The effectiveness of the mechanical holding device described in this paper has not been determined conclusively.
4. The hyoid triangle provides an alternative method to determine hyoid bone position.
5. No one particular factor of the five determinants of facial type affected all of the hyoid triangle measurements.
6. To have any influence on the hyoid triangle measurements, all five determinants of facial type must be used.
7. The vertical measurements of the hyoid triangle H-H' and Hyoid Plane Angle showed the most variation between the first and second radiograph.
8. There was a large variation in head position, as shown in the MGP-OP angle.

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APPENDIXES

Appendix A

Patient Data on First Radiograph of Hyoid Triangle

MGP-OP angle and Hyoid P.A. are in degrees, all others are in millimeters

Patient Number	C3-RGn	C3-H	H-RGn	H-H'	Hyoid P.A.	AA-PNS	OA	MGP-OP Angle
1.	76	34.5	41.5	+2.5	27	36	5	70
2.	70	37.5	34	-5.5	12	38	14	61
3.	61.5	30	32	+3.5	7	33.5	8	72
4.	67.5	36.5	31	-2	9.5	41.5	2	78
5.	77.5	36.5	42	-5	18	39	8	72
6.	59	28.5	30.5	+3	16	32.5	10	72
7.	70.5	39.5	32	-6	17	34	5	78.5
8.	57.5	35	22.5	+.5	0	39	10	60
9.	62	31.5	31	-3.5	12	34	12	64

Appendix A Continued

Patient Number	C3-RGn	C3-H	H-RGn	H-H'	Hyoid P.A.	AA-PNS	OA	MGP-OP Angle
10.	79	38	41.5	+4	18	41.5	7	90
11.	72	31.5	40.5	+.5	22	42	7.5	66
12.	62	39.5	24	-6.5	17	32.5	10.5	70
13.	82.5	40	44	-8	28	35.5	3	76.5
14.	65.5	26.5	40	+6.5	12	37	10	75.5
15.	63	30.5	33	-2	23	33.5	7.5	70.5
16.	89.5	39	50	+1.5	33.5	39.5	3.5	90
17.	67	34	35	-7.5	33	32	7.5	75
18.	74.5	33.5	41.5	+5	18	31	5	86.5
19.	63	34.5	28.5	+.5	5.5	38	10	72
20.	71.5	32	39	+3	27.5	32	5.5	97

Appendix A Continued

Patient Number	C3-RGn	C3-H	H-RGn	H-H'	Hyoid P.A.	AA-PNS	OA	MGP-OP Angle
21.	81	40	44.5	-11	10	43.5	9	53.5
22.	73	39.5	33.5	+.5	21	33.5	8	86
23.	85	38.5	46.5	0	14	49.5	6.5	84
24.	69	28.5	41	+1	13	36.5	5	70
25.	61	46	17.5	-6.5	19.5	30.5	8.5	81
26.	51.5	34	18	-2	16.5	28	6.5	74.5
27.	88.5	42	47.5	+6.5	14.5	42.5	7.5	85
28.	66.5	37	30	+2.5	4.5	46.5	7	66.5
29.	70.5	33	39	-7	37	35	10.5	88
30.	79.5	34	47	-7.5	17	39	9	74

Appendix B

Patient Data on Second Radiograph of Hyoid Triangle

MGP-OP angle and Hyoid P.A. are in degrees, all others are in millimeters

Patient Number	C3-RGn	C3-H	H-RGn	H-H'	Hyoid P.A.	AA-PNS	OA	MGP-OP Angle
1.	75.5	37.5	37.5	-2	20	35.5	5.5	71
2.	68.5	36	34	-6	8.5	36.5	12	59
3.	62	30	32	+3	3	34	8	71
4.	69	36	33	-2	13	42	2	78
5.	78.5	36.5	43.5	-7	22	39.5	9	71
6.	57.5	28	29.5	0	22	32.5	9	73
7.	69.5	38	32.5	-5	10	32	4	76.5
8.	57.5	36.5	21	+.5	0	38.5	10	59.5
9.	63.5	31.5	-1.5	-1.5	15	37.5	12	65.5

Appendix B Continued

Patient Number	C3-RGn	C3-H	H-RGn	H-H'	Hyoid P.A.	AA-PNS	OA	MGP-OP Angle
10.	79.5	35	44.5	-2	16	44	6.5	90
11.	72	32	40	-1	16.5	44	9	64.5
12.	62	41	23.5	-8	30	31.5	11	68
13.	79.5	41	40	-6.5	22.5	32.5	4.5	73
14.	66	29	38.5	+6.5	11	37.5	10.5	74
15.	62	31.5	31	-2.5	27	32.5	7.5	70
16.	88	38.5	49.5	+.5	30	38.5	5	89
17.	60.5	34	27.5	-6	27.5	30	9	69
18.	74.5	34	41.5	+6.5	18.5	29.5	5	86
19.	64.5	35	29.5	+1.5	2	39	10	72
20.	71	32.5	38.5	+3	38	32.5	6	97

Appendix B Continued

Patient Number	C3-RGn	C3-H	H-RGn	H-H'	Hyoid P.A.	AA-PNS	OA	MGP-OP Angle
21.	80.5	39.5	44	-11	11.5	43.5	9	54
22.	71.5	39.5	32	+.5	14	38.5	8	85
23.	87	38.5	48	+2.5	15	49.5	6.5	85
24.	67.5	29.5	38	-2	13	34	4.5	69.5
25.	61.5	47	19	-10.5	21	30.5	8.5	82
26.	52	33.5	19	-2.5	16	31	7	74
27.	88.5	42.5	46.5	+6.5	14	41.5	7	86
28.	67.5	37	30.5	+3	7.5	47.5	7.5	67
29.	69.5	32.5	37.5	-3	34	32.5	10	86
30.	79	34	47	-8.5	21	37.5	8.5	74

Appendix C

Facial Type Data

All measurements are in degrees

Patient Number	Facial Axis	Cranial Def.	Lower Face H	Mand. Arc	Mand. Plane	Facial Type
1.	94	27	40	28	22	B
2.	95	27.5	41.5	24.5	23	B
3.	84	26	47.5	28.5	29.5	M
4.	78.5	33.5	53	22	31.5	D
5.	96	27.5	41.5	37.5	11.5	B
6.	88.5	26	47.5	27	24	M
7.	86	30	50	25.5	25	D
8.	88.5	27.5	55	24	30.5	D
9.	90	30	46	27.5	20	M
10.	83.5	30	48	23	27.5	D
11.	93	30	43	34	15.5	B
12.	82.5	30.5	56	27.5	27.5	D
13.	91	29	45	25	23	M
14.	82.5	30.5	52	24.5	31	D
15.	85	29	46	23.5	28	M
16.	88.5	28	48	18.5	31.5	M
17.	88.5	31	44	31.5	21.5	M
18.	88.5	28	49	33.5	25	M

Appendix C Continued

Patient Number	Facial Axis	Cranial Def.	Lower Face H.	Mand. Arc	Mand. Plane	Facial Type
19.	86.5	32	47.5	29.5	19	M
20.	84.5	31.5	49	27.5	28	M
21.	98.5	26	43	32.5	19.5	B
22.	75	32.5	61	24	33	D
23.	91	32.5	41.5	27.5	15	B
24.	91	30.5	42	29.5	18	B
25.	81	33	53	29.5	23.5	D
26.	81.5	27	52	25.5	36	D
27.	88.5	26.5	46	27	27	M
28.	87	26	51	23.5	30.5	D
29.	85	32.5	45.5	31.5	19.5	M
30.	94.5	28.5	44	32	16.5	B