A ROENTGENOCEPHALOMETRIC STUDY ON THE POSITION OF THE HYOID BONE*

BY

Takayuki KURODA, Eisaku NUNOTA, Kooji HANADA, Gakuji ITO and Yoshinobu SHIBASAKI**

ABSTRACT

The position of the hyoid bone as related to the cranial base and to the mandible was investigated. The materials used in this study were twenty Japanese adults of both sexes with normal occlusion, and twenty orthodontic cases with upper protrusion (Angle Class II division 1), and twenty lower protrusion cases (Angle Class III). The Hellman's dental age analysis of these clinical cases was between III-C and IV-A.

The position of the body of the hyoid as related to the cranial base showed a significant difference among these three groups.

Compared with the normal occlusion group, the body of the hyoid was located slightly backward in the upper protrusion group and slightly forward in the lower protrusion.

However, in relation to the mandible, position of the body of the hyoid was constant in these three groups.

In order to confirm the stability of the relative position of the hyoid to the mandible, following two cases were investigated; an ankylosis of the temporomandibular joint and a case of lower protrusion with severe distortion of the cervical vertebra caused by tuberculosis of spines. In the former case, the mandible was located far backward in relation to the cranium, while that of the latter was located far forward. However, the relative position of the hyoid to the mandible seemed to be stable in these two cases. The hyoid as related to the cranial base varied when the mandible took anteroposterior malpositions to the cranium. Considering the fact that the hyoid position as related to the mandible was stable, the muscles which connect them seemed to play an important role in the displacement of the mandible.

INTRODUCTION

In the field of orthodontics, it is necessary from etiological and clinical aspects to understand clearly the effect of function of the masticatory organs on the growth and development of the dentofacial complex. Thompson[16),

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** 黒田敬之, 布田栄作, 花田晃治, 伊藤学而, 柴崎好伸: Department of Orthodontics (Chief: Prof. F. MIURA), School of Dentistry, Tokyo Medical and Dental University (Tokyo Ika Shika Daigaku).

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Brodie[9], Graber[11], and Ricketts[14] stated that the function of the tongue and the suprahyoid muscles affected the development of the dentofacial complex. They also pointed out that it is important to examine the hyoid bone for the purpose of clarifing the relationship between function and morphology.

Certainly, it is easily seen that the function of the tongue and the muscles attached to the mandibular bone would affect the growth and development of the dentofacial complex, especially those of the mandible. Morphological examination of the hyoid bone is considered to be a reasonable approach for analysing the effect of function on the form, because the hyoid bone is supported by the muscles and does not have an osseous connection with the cranium and the mandible, and its position is dependent on the balance of surrounding soft tissues.

In the past, many investigations on the hyoid bone from anatomical and genetic aspects were made[2-5,8,13], but only a few investigators studied the position of the hyoid bone as related to the cranium, the mandible, and the cervical vertebra[6,7,10,12,15]. Especially, from the orthodontic point of view, there has been no study on the hyoid bone to examine the functional effect on the morphology. In the present study, interrelation between the hyoid bone and the cranium, and mandible was examined by using roentgenocephalometrics in an attempt to clarify the function of the tongue and suprahyoid muscles on the antero-posterior position of the mandible to the cranium.

Materials

Twenty roentgenocephalograms of Japanese adults of both sexes with normal occlusion were selected from the orthodontic files of the Orthodontic Clinic of Tokyo Medical and Dental University. In addition, head plates of twenty cases of upper protrusion (Angle Class II division 1) and twenty cases of lower protrusion (Angle Class III), Hellman's dental age between III-C and IV-A, were selected from both sexes.

These materials are shown in Table 1.

Method

Points measured were as follows (Fig. 1): The center of Sella turcica (S), Nasion (N), Point A, Point B, Pogonion (P), Gnathion (Gn), Articulare (Ar), Gonion (Go), Menton (Me), Bolton (Bo), and the intersection of two lines extending from Ar-Go and N-S (Z).

In addition to these points, the center of the body of the hyoid bone (H) was used as the indicative landmark of the hyoid bone.

Table 1. Classification of the materials

Classification	Sex	Number	Age		
			mean	max.	min.
Normal occlusion	male	20	20 y. 8 m.	25 y. 6 m.	18 y. 6 m.
	female	20	23 y. 6 m.	26 y. 11 m.	19 y. 0 m.
Upper protrusion (Angle class II div. 1)	male	20	18 y. 1 m.	24 y. 9 m.	11 y. 0 m.
	female	20	16 y. 7 m.	25 y. 0 m.	10 y. 10 m.
Lower protrusion (Angle class III)	male	20	13 y. 8 m.	24 y. 6 m.	11 y. 0 m.
	female	20	15 y. 4 m.	23 y. 6 m.	10 y. 0 m.

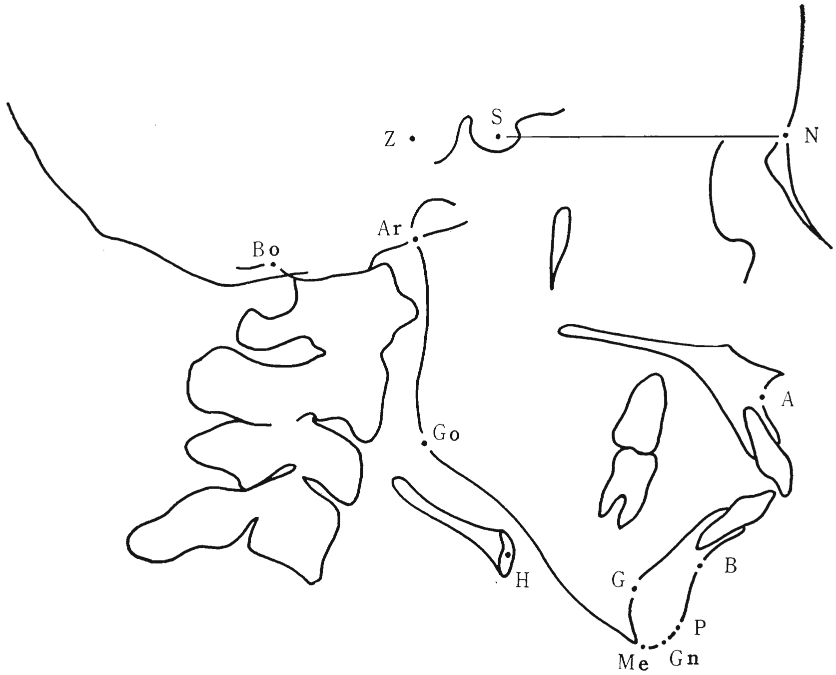

Fig. 1. Points selected for measurement.

Bench[7] and others used the most anterosuperior point of the body of the hyoid bone to indicate the position of the hyoid bone, but this point seemed to be variable according to the rotation of the hyoid bone itself. This is the reason why the center of the body of the hyoid bone was selected in the present study.

Among the suprahyoid muscles, only the digastric muscle connects the hyoid bone to the cranial base and to the mandible. The digastric muscle consists of the anterior and posterior venter, and the intermediate tendon of the muscle is fixed to the hyoid bone by the fibrous trochlea at the small horn of hyoid. The posterior venter starts from the incisula mastoidea and runs downward and forward to the intermediate tendon. The anterior venter runs inward and forward, and attaches to the mandibular digastric fossa.

For the purpose of the present study, the length of this muscle is considered to be a very useful tool for positional determination of the hyoid bone. Considering the attachment of the anterior venter to the mandible, the genial tubercule (point G) which is located close to the digastric fossa was also used. Considering the attachment of the posterior venter to the cranium, the Bolton point was used for the point covered by the shade of the mastoidea tubercle.

Following angles and distances were measured (Fig. 2).

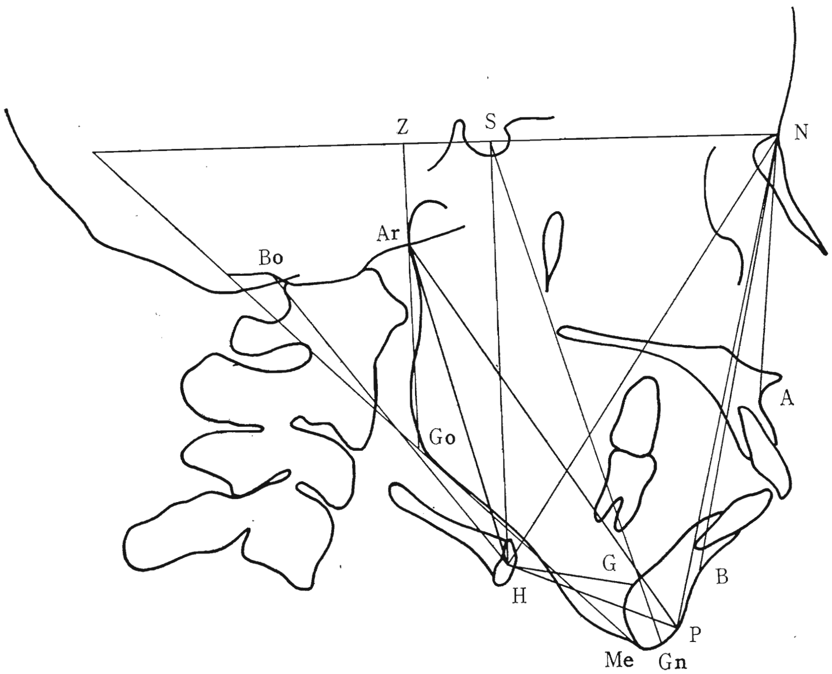

Fig. 2. The method of measurement.

(A) Angular measurement

(1) SNA (2) SNB (3) SNP (4) SN-Gn (5) SN-GoMe (6) GZN (7) HSN (8) HNS (9) Ar PH (10) PArH

(B) Linear measurement (in centimeter)

(11) $\overline{NS}$ (12) $\overline{Ar\text{-}P}$ (13) $\overline{HG}$ (14) $\overline{HBo}$

Each mean, standard deviation, and standard variance were computed and the differences at the 1% level of significance of each group were also calculated.

Results

The results obtained are illustrated in Tables 2 and 3.

I. The anteroposterior position of the maxillary basal bone as related to the anterior cranial base (NS):

No significant differences were found in the SNA angle between the normal occlusion group (male 80.9°, S.D. 3.8; female 82.2°, S.D. 2.6), upper protrusion group (male 80.7°, S.D. 3.8; female 80.0°, S.D. 2.6), and the lower protrusion group (male 79.3°, S.D. 3.3; female 79.2°, S.D. 3.3).

II. The position of the mandible as related to the anterior cranial base:

Significant differences were found in SNB and SNP angles among the three groups: Normal occlusion group (male ∠SNB 78.2°, S.D. 3.0, ∠SNP 78.7°, S.D. 2.9; female ∠SNB 78.4°, S.D. 3.1, ∠SNP 78.1°, S.D. 3.6). Upper protrusion group (male ∠SNB 75.9°, S.D. 4.8, ∠SNP 76.4°, S.D. 5.0; female ∠SNB 74.5°, S.D. 2.8, ∠SNP 74.2°, S.D. 3.5). Lower protrusion group (male ∠SNB 81.5°, S.D. 3.3, ∠SNP 81.0°, S.D. 3.2; female ∠SNB 82.3°, S.D. 4.5, ∠SNP 81.6°, S.D. 4.2).

Compared with the normal occlusion group, the mandible was located slightly backward in the upper protrusion group, while it was located slightly forward in the lower protrusion group.

On examination of the factors of rotation of the mandible (∠SN-Gn, Sn-GoMe, GZN), there seems to be no specific tendency that may be derived from the nature of the significances (Table 3) found in these three groups.

III. The position of the body of the hyoid as related to the anterior cranial base $\overline{(NS)}$:

$\overline{NS}$: Significant differences were observed between normal occlusion group (male 7.3 cm, S.D. 0.3) and lower protrusion group (male 6.7 cm, S.D. 0.3), and between upper protrusion group (male 7.1 cm, S.D. 0.3; female 6.8 cm, S.D. 0.3) and lower protrusion group (male 6.7 cm, S.D. 0.3; female 6.5 cm, S.D. 0.3).

∠HSN: Significant differences were found between normal occlusion

Table 2. Results of the measurements.

Normal occlusion		SNA	SNB	SNP	SN-Gn	SN-Mand	GZN	NS	ArP	HSN	HNS	PArH	ArPH	HG	HBo
Male	Mean	80.9	78.2	78.7	71.2	33. 8	90.4	7.3	12.0	91.6	54.7	23.3	41.5	3.9	9.9
	Max.	86.2	83.5	83.0	75.0	44. 0	97.3	7.8	12.8	97.0	65.0	28.0	58.0	5.0	11.4
	Min.	76.0	74.0	74.0	66.5	19. 0	82.0	6.7	11.3	84.0	52.5	16.0	34.0	2.9	8.4
	μ^2	7.67	9.19	8.16	9.80	33.85	17.94	0.11	0.18	11.89	13.65	13.72	25.68	0.39	0.56
	S.D.	2.7	3.0	2.9	3.1	5. 7	4.1	0.3	0.4	3.4	3.7	3.6	5.1	0.6	0.8
Female	Mean	82.2	78.4	78.1	71.6	35.1	93.9	6.8	11.0	92.5	59.6	23.2	37.5	3.7	8.8
	Max.	88.0	82.5	84.0	78.0	48.0	104.5	7.2	11.9	98.5	60.5	29.01	45.5	4.8	9.6
	Min.	78.0	71.5	71.0	66.5	26.0	84.0	6.4	10.0	86.0	49.5	5.5	30.0	3.0	7.5
	μ^2	6.47	10.47	12.65	12.55	41.81	27.68	0.07	0.28	11.11	31.10	9.67	20.01	0.23	0.37
	S.D.	2.6	3.1	3.6	3.5	6.5	5.3	0.3	0.5	3.3	5.6	3.1	4.5	0.5	0.6
Upper protrusion															
Male	Mean	80.7	75.9	76.4	73.2	35.9	93.3	7.1	11.6	93.8	57.0	23.7	42.9	3.8	9.2
	Max.	92.0	85.0	86.0	82.0	50.5	102.0	7.8	14.0	102.5	74.0	28.5	53.0	5.3	10.6
	Min.	74.5	69.0	69.0	64.2	21.5	84.9	6.6	9.4	82.5	50.0	17.0	31.0	2.8	7.2
	μ^2	14.53	22.91	24.87	22.34	79.67	21.34	0.13	1.14	17.44	42.14	9.8	29.36	0.38	0.94
	S.D.	3.8	4.8	5.0	4.7	8.9	4.6	0.3	1.1	4.2	6.5	3.0	5.4	0.6	1.0
Female	Mean	80.0	74.5	74.2	75.2	40.3	96.2	6.8	10.8	96.8	51.8	24.8	38.4	3.7	8.3
	Max.	84.5	79.5	80.0	87.0	55.0	113.5	7.3	13.8	110.0	57.0	39.0	56.0	4.6	9.6
	Min.	75.0	68.0	65.0	68.5	27.0	84.0	5.9	9.2	92.0	45.0	12.5	21.0	2.7	6.8
	μ^2	6.81	7.82	11.94	17.54	36.64	28.37	0.09	1.22	18.43	7.23	29.35	73.84	0.39	0.61
	S.D.	2.6	2.8	3.5	4.2	6.1	5.3	0.3	1.1	4.3	2.7	5.3	8.6	0.6	0.8
Lower protrusion															
Male	Mean	79.3	81.5	81.0	69.8	36.7	88.5	6.7	11.2	90.3	58.4	23.5	41.3	3.8	9.0*
	Max.	83.5	86.6	86.5	75.0	49.0	98.0	7.6	12.2	99.0	65.0	33.0	57.9	5.5	10.8
	Min.	74.0	76.0	75.0	66.0	25.0	81.0	6.3	10.3	84.0	50.5	15.0	30.0	2.4	7.5
	μ^2	9.26	10.89	10.36	8.34	34.44	28.93	0.1	0.50	15.67	18.24	30.19	43.34	0.68	0.94
	S.D.	3.3	3.3	3.2	2.9	5.9	5.4	0.3	0.7	4.0	4.3	5.5	6.6	0.8	0.9
Female	Mean	79.2	82.3	81.6	68.5	35.5	87.3	6.5	11.1	89.8	58.2	24.3	39.7	3.8	8.6
	Max.	84.5	88.3	88.5	73.0	41.0	94.0	7.3	12.3	98.0	63.2	33.5	56.0	5.2	10.3
	Min.	72.0	74.0	72.5	61.5	26.3	76.0	6.0	10.0	81.0	53.0	17.0	31.0	3.1	6.6
	μ^2	10.79	20.23	17.85	13.68	19.55	24.69	0.1	0.41	21.45	14.34	18.34	37.29	0.23	0.77
	S.D.	3.3	4.5	4.2	3.7	4.4	5.0	0.3	0.6	4.6	3.8	4.3	6.1	0.5	0.9

μ^2: unbiased estimate of population variance, * : This figure was obtained from 19 cases.

Table 3. Significance of difference among the groups

	SNA	SNB	SNP	SN–Gn	SN-M and	GZN	NS	ArP	HSN	HNS	PArH	ArPH	HG	HBo
Normal M Normal F	–	–	–	–	–	–	–	+	+	+	–	–	–	+
Normal M U. Prot. M	–	–	–	–	–	–	–	–	–	–	–	–	–	+
Normal F U. Prot. F	–	+	+	+	–	–	–	–	+	+	–	–	–	–
Normal M L. Prot. M	–	+	–	–	–	–	+	+	–	+	–	–	–	+
Normal F L. Prot. F	–	+	+	–	–	+	–	–	–	–	–	–	–	–
U. Prot. M L. Prot. M	–	+	+	+	–	+	+	–	+	–	–	–	–	–
U. Prot. F L. Prot. F	–	+	+	+	+	+	+	–	+	+	–	–	–	–

Normal M: normal occlusion male
Normal F: normal occlusion female
U. Prot. M: upper protrusion male
L. Prot. M: lower protrusion male
U. Prot. F: upper protrusion female
L. Prot. F: lower protrusion female
–insignificant on 1% level of significance
+significant on 1% level of significance

group (female 92.5°, S.D. 3.3) and upper protrusion group (female 96.8°, S.D. 4.3), and between the upper protrusion group (male 93.8°, S.D. 4.2; female 96.8°, S.D. 4.3) and the lower protrusion group (male 90.3°, S.D. 4.0; female 89.8°, S.D. 4.6).

∠HNS: Significant differences were observed between female of normal occlusion group (59.6°, S.D. 5.6) and female of upper protrusion group (51.8°, S.D. 2.7), and between male of normal occlusion group (54.7°, S.D. 3.7) and male of lower protrusion group (58.4°, S.D. 4.3). Significant difference was also observed between upper protrusion group (female 51.8°, S.D. 2.7) and lower protrusion group (female 58.2°, S.D. 3.8).

From the foregoing facts mentioned, a triangle that has line $\overline{NS}$ as the base and point H as the top can be drawn (Fig. 3). Compared with the normal occlusion group, point H is located backward and downward in the male of upper protrusion group, and backward and upward in the female of upper protrusion group. Point H is located slightly forward and downward in the male of lower protrusion group, and forward and upward in the female of lower protrusion group.

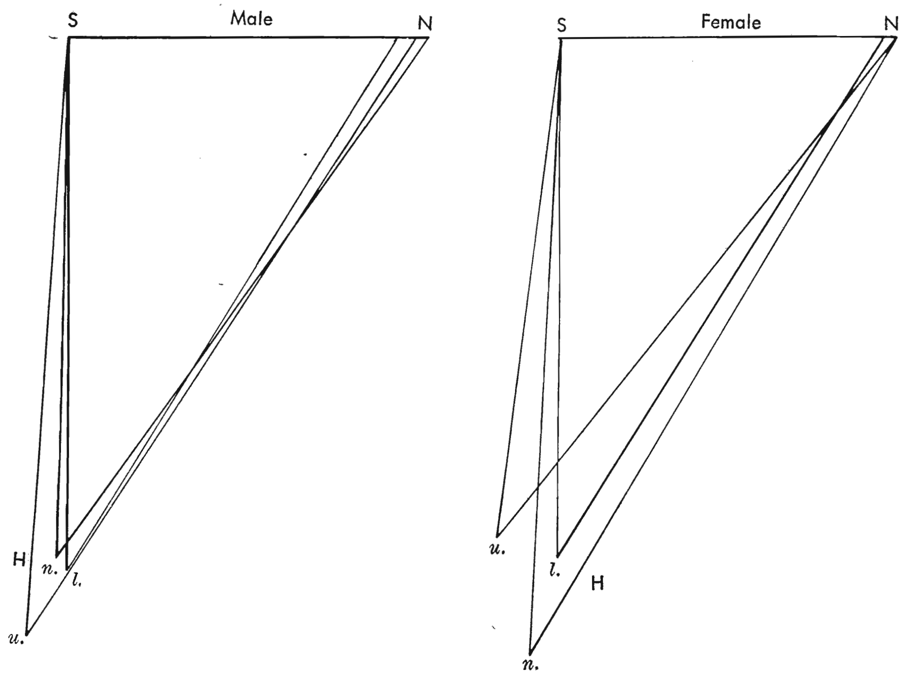

Fig. 3.

In summary, the location of point H which was backward in the upper protrusion group and forward in the lower protrusion group was common in both sexes.

IV. The position of the body of the hyoid as related to the mandible:

$\overline{\text{ArP}}$: Harris nominated the point A, at superior point of the condylar head, and measured the distance between the point A and the point farthest from the point A as mandibular length. In the present study, however, determination of the point A was so difficult because the image of the condylar head is always vague in the head plates that the point Ar was used for the point, and the distance from the point Ar to the Pogonion was used for the mandibular length.

A significant difference was observed between normal occlusion (male 12.0 cm, S.D. 0.4) and lower protrusion group (male 11.2 cm, S.D. 0.7).

∠ArPH: In both sexes, no significant differences were observed among the normal occlusion group, the upper protrusion group, and lower protrusion group.

From these facts, a triangle can be drawn which has the line $\overline{\text{ArP}}$ as the base and the point H as the top (Fig. 4). Three triangles of the normal occlusion group, the upper protrusion group, and the lower protrusion group were almost similar in both sexes. In each group, position of the hyoid varied largely when it was related to the anterior cranial base, but varied less when related to the mandible.

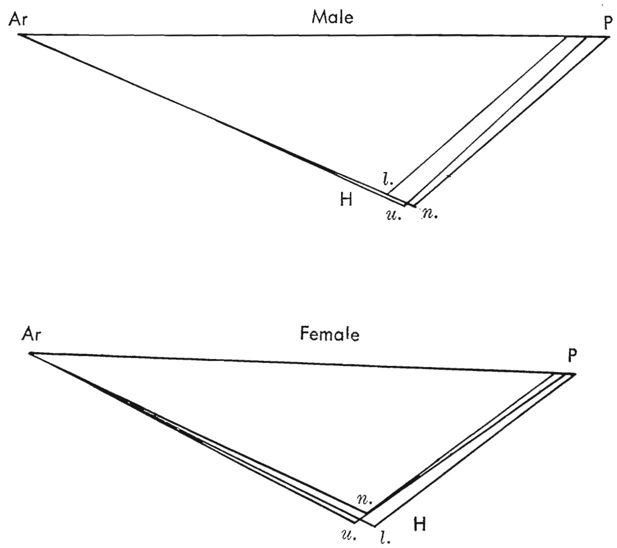

Fig. 4.

V. The length of the anterior and posterior venters of the digastric muscle:

$\overline{\text{HG}}$: The distance of HG, representing the length of the anterior venter

of the muscle, showed no significant differences in three groups of occlusion.
$\overline{HBo}$: The distance of $\overline{HBo}$, representing the length of the posterior venter of the muscle, showed significant differences between male normal occlusion group (9.9 cm, S.D. 0.8) and the upper protrusion group (9.2 cm, S.D. 1.0), and between male normal occlusion group and the lower protrusion group (9.0 cm, S.D. 0.9).

Discussion

I. Geometrical position of the hyoid bone as related to the cranium and the mandible:

Since the hyoid bone is suspended by muscles to the skull, the mandible, and the structures in the laryngeal region, a relative position of the hyoid to them would be unstable.

However, Bench and Brodie[7] pointed out that the hyoid descends corresponding with the development of the cranium, mandible, and cervical region, and its position relative to these areas remains the same.

Grant[12] studied the position of the hyoid in Class I, II, and III malocclusions. He measured the angle formed by line SN and line SH (H: the most superior point on the body of the hyoid bone, and examined a line through Gnathion and point H to the cervical vertebra. He found that the hyoid position is constant in three types of malocclusion.

The present study indicates that the body of the hyoid bone as related to the cranial base is located slightly backward in the upper protrusion group and slightly forward in the lower protrusion group compared with the normal occlusion group.

However, this relation is not the same in reference to the mandible; the body of the hyoid bone as related to the base of skull moves in response to the antero-posterior movement of the mandible. This fact may suggest a close connection between the mandible and the body of the hyoid bone.

To confirm the stability of the relative position of the hyoid to the mandible, the following two cases were investigated; first was a case of ankylosis of the temporo-mandibular joint (Fig. 5) and the second was a case of the lower protrusion with severe distortion of the cervical vertebra (Fig. 6) caused by tuberculosis of spine with a marked antero-posterior displacement of the mandible to the cranium. The values of these measurements were plotted on a polygon drawn by using means and standard deviation of the normal occlusion group (Tables 4 and 5). The results were as follows:

(a) An ankylosis of the temporo-mandibular joint was found in a Japanese male, aged 16 years and 6 months.

Fig. 5. The tracing of the patient with ankylosis of the temporo-mandibular joint (16 y. 6 m. male).

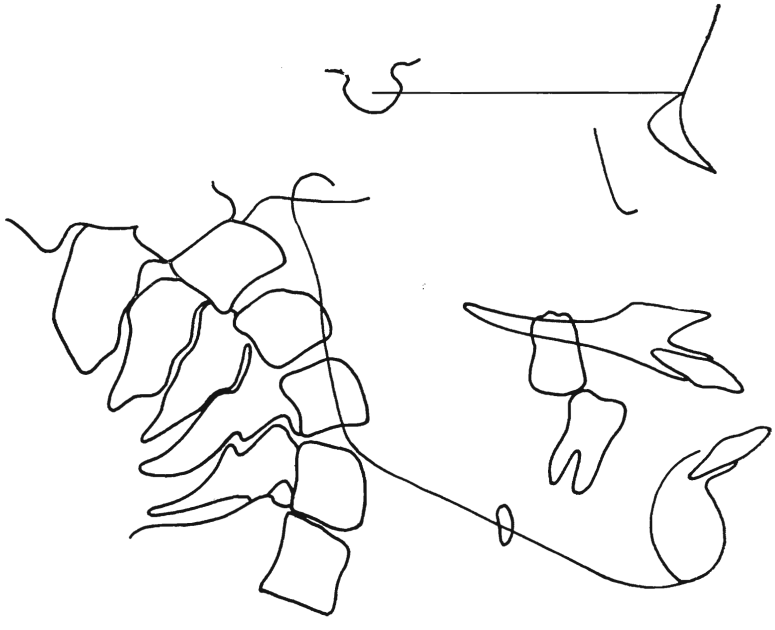

Fig. 6. The tracing of the patient with mandibular protrusion caused by the tuberculosis of the spine (26 y. 11 m. female).

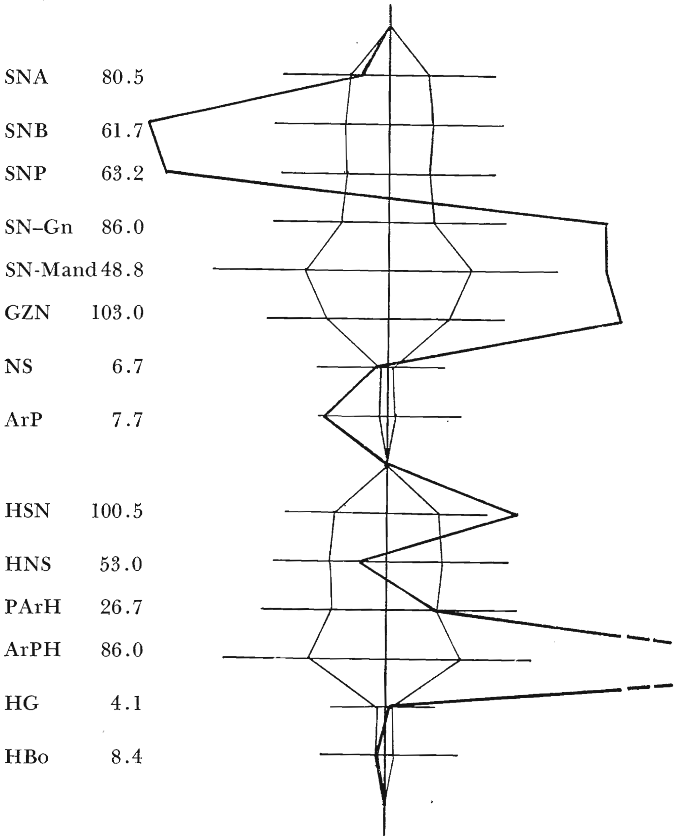

Table 4. Plotting the measurement of the patient with ankylosis of the temporo-mandibular joint on the polygon obtained from normal occlusion data.

All the measurements except ∠SNA, $\overline{\mathrm{NS}}$, ∠HNS, $\overline{\mathrm{HG}}$, and $\overline{\mathrm{HBo}}$ showed either dominance or recession of more than 1 S.D.. Especially $\overline{\mathrm{ArP}}$ showed dominance of more than 3 S.D.. However, the values of ∠ArPH, $\overline{\mathrm{HG}}$, and $\overline{\mathrm{HBo}}$ which were not so deviated prove the hyoid to be more stable as related to the mandible than the other reference. The body of the hyoid moves backward and downward in response to the displacement of the mandible.

(b) A lower protrusion with severe distortion of the cervical vertebra caused by tuberculosis of spine, Japanese female, aged 26 years and 11 months.

All the measurements except $\overline{\mathrm{NS}}$, ∠ArPH, and $\overline{\mathrm{HG}}$ showed dominance or recession of more than 1 S.D.. In this case, the body of the hyoid seemed to be dislocated forward in response to the marked forward displacement

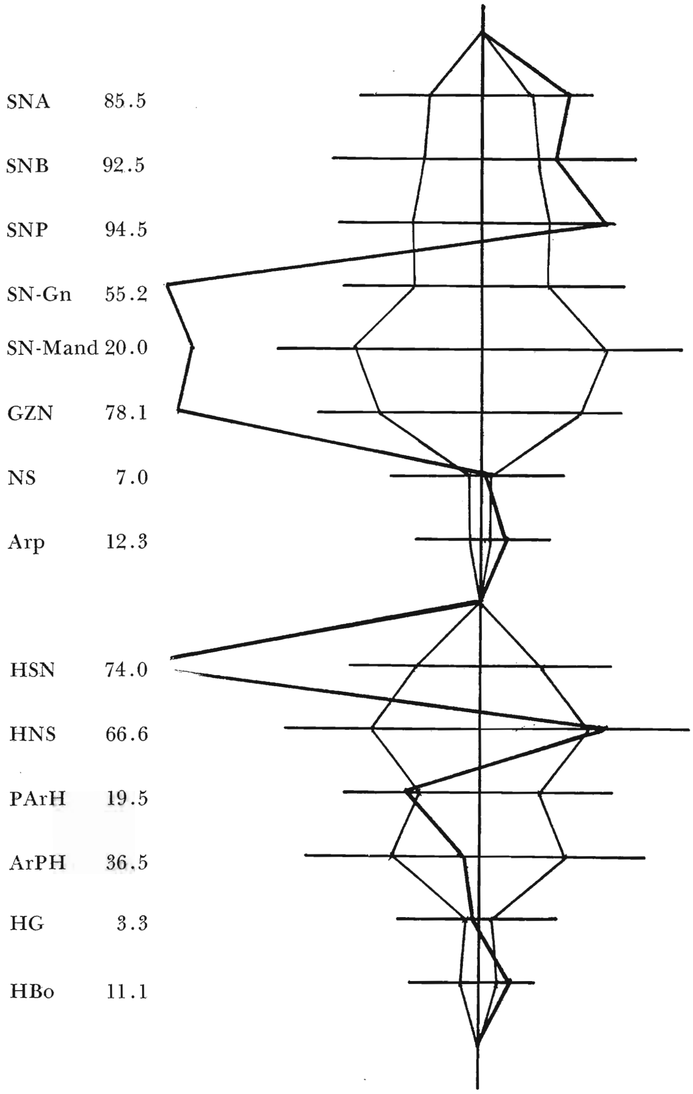

Table 5. Plotting the measurement of the patient with mandibular protrusion caused by the tuberculosis of the spine on the polygon obtained from normal occlusion data.

of the mandible. It should be noted that the deviation of the measurements of $\overline{HG}$, and $\overline{HBo}$ was far less than that of the others. In the case of an ankylosis of the temporo-mandibular joint, movement of the tongue and the mandible had been disturbed and restrained since 1 year and 5 months after birth. In a lower protrusion with severe distorsion of the cervical vertebra caused by tuberculosis of spine, cervical area showed an abnormal development because of the forward displacement of the pharyngeal and laryngeal areas by severe distortion of cervical vertebra. In spite of these facts the length of the muscle which connects the hyoid to the mandible and the cranial base was found to be almost normal.

In these two cases, the position of the hyoid as related to the mandible was also found to be nearly stable as seen in the normal occlusion group and malocclusion groups. A geometrical rule that the position of the hyoid as related to the cranial base is dislocated in the same way as the mandible was endorsed by the above facts.

II. Discussion from the genesis of mandible and hyoid:

Many investigators recognize that the mandible develops from the first branchial arch, and the hyoid develops from the second and third branchial arches[5]. Despite the difference in the genesis of these bones, they are connected by many muscles developed from the first, second, and third branchial arches.

The fact that position of the hyoid as related to the mandible is constant, irrespective of the antero-posterior displacement of the mandible to the cranial base, seems to be explainable only by the function of the muscles that connect both of them. The mandible is suspended by masticatory muscles from the cranium. The hyoid is connected with the cranium by the muscles developed from the second and third branchial arches, and it is also connected to the mandible by two types of muscle developed from the first branchial arch and the muscles from the second and third branchial arches. These three bones are contained in soft tissues. From the nature of the genesis, a relative position of the cranium, the mandible, and the hyoid seems to be determined by a balance of surrounding soft tissues.

Soft tissues which hold the mandible and the hyoid are thought to influence largely the relative position of the cranium, the mandible, and the hyoid, since there is some genetic or physiological pecuriality in muscles that connect the hyoid with the mandible.

Besides, as Stepovich[15] pointed out, in the cephalometric study on the position of the hyoid, variation of the posture changes the position of the hyoid. Consequently, statistical re-examination of the range of allowance of these variation becomes very important.

In conjunction with this problem, the position of the hyoid is varied largely when the subject is instructed to keep the mandible in centric occlusion, at rest position, maximum opening, and in swallowing (Fig. 7).

These physiological examinations concerning various jaw movements would bring a better understanding of the behavior of the hyoid. Consequently, these findings may possibly give some implications for genesis of

Fig. 7. A scheme showing the movements of hyoid bone in different mandibular positions.
A: Centric occlusion B: Rest position
C: Swallowing D: Opening

antero-posterior malocclusion.

Conclusion

Position of the hyoid as related to the cranial base and the mandible was studied by roentgenocephalograms, and the conclusions are as follows:

(1) As related to NS (anterior cranial base): The position of the body of the hyoid showed a significant difference among normal group, upper protrusion group, and lower protrusion group. The body of the hyoid was located slightly backward in upper protrusion group and a little forward in lower protrusion group compared to the normal occlusion group.

(2) As related to the mandible: The hyoid position is constant in all three groups. Distances from the mandible and the cranial base (Bolton point) to the body of the hyoid are almost constant in three types of occlusion. (Lines drawn from the point H through Bolton point and through

point G run nearly parallel with the running of digastric muscle).

(3) In the case of an ankylosis of the temporo-mandibular joint, the mandible is located far backward relative to the cranium. In the case of a lower protrusion with severe distortion of the cervical vertebra caused by tuberculosis of spine, the mandible is located far forward relative to the cranium. The position of the hyoid relative to the mandible, however, was found to be nearly stable. The hyoid relative to the cranial base varies depending on antero-posterior position of the mandible in relation to the cranium.

(4) Considering the fact that the hyoid position relative to the mandible is stable, the muscles which connect the hyoid and the mandible seem to affect largely the antero-posterior displacement of the mandible in relation to the cranium.

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