Growth Behavior Of The Hyoid Bone

CARMINE A. DURZO, D.D.S., M.S.
ALLAN G. BRODIE, D.D.S., Ph.D.
Chicago, Illinois

INTRODUCTION

Previous studies of the components of the human skull have shown a pattern which tends to remain stable after the second or third month of life. Thus, Brodie stated in 1941, "The most important single finding is that the morphogenetic pattern of the head is established by the third month of postnatal life, or perhaps earlier, and that once attained it does not change."

Later in the same work, he makes the statement, "Each part, and probably each bone, is growing at a constantly diminishing rate. The various individual growth patterns are so integrated, however, that the resulting course is a straight line for any given anatomical point."

These studies, however, have dealt primarily with those bones in direct contact with other bones. The question arose, how a floating bone, such as the hyoid which has no contact with other bony structures, would react when studied during a period of growth of the individual. This is the problem the authors wished to investigate.

REVIEW OF LITERATURE

Considering the vital functions with which the hyoid bone is associated, it is surprising to note the very few references to it in the literature. The majority of these are anatomical descriptions and only occasionally does one find consideration given to its functions and behavior.

According to most comparative anatomists the hyoid bone has been subject to Williston's Law, viz., that phylogenetic development of the skeleton has witnessed a reduction in the number of bones with an increase in the complexity of those that have survived. However, in the lower forms of life the parts which form the hyoid bone are referred to as an apparatus which has for its function laryngeal scaffolding and tongue support.

Flowers (1885), in describing the osteology of the Mammalia, showed a comparison between the hyoid systems of the dog and man. In the dog there is present a stylohyal, epihyal, ceratohyal, and tympanohyal; these comprise the anterior cornus. The basihyal forms the body and the thyrohyal, the posterior cornua. In man there remain the basihyal, ceratohyal, and thyrohyal. The stylohyal of the dog becomes the styloid process in man. The tympanohyal becomes surrounded by the tympanic portion of the temporal bone and the epihyal shows no ossification in man.

Kingsley (1912), in his comparative anatomy of vertebrates, wrote that the skeleton of the Mammalian tongue (hyoid apparatus) varies considerably. In its most complete development it consists of a body in the median line which bears two pairs of cornua.

Neal and Rand (1936) state that evidence from both comparative anatomy and embryology indicates that the upper and lower jaws, the hyoid bone, the ear bones, and the laryngeal cartilages of man have evolved from the skeletal gill supports of primitive fishes. The cartilages of the second and third visceral arches ossify to form the hyoid and its cornua.

In 1930 Negus published his *Mechan-*

ism of the Larynx. This is, by all odds, the most complete and authoritative work on the throat structure. He stated that the hyoid of many of the lower vertebrates is in closer relationship with the larynx than in higher orders. In all mammals, however, the larynx, although not intimately united with the hyoid, is indirectly attached to it and certain muscles pass from one to the other. Negus postulated also that the hyoid bone and larynx are both influenced by the position of the head.

Sprague (1943) wrote that the evolution of the hyoid region is closely associated with the development and changes of the mechanisms of breathing, swallowing, phonation, and with the development of the tongue.

Thompson (1941) stated that the hyoid is influenced by mandibular movements. In mouth openings, since the mandible moves downward, one might expect the hyoid to do the same. Thompson found that this did not occur. The hyoid tends to remain at a constant level, moving slightly backward.

Mainland (1945) describes the hyoid as a platform which can be fixed by one set of muscles so that other muscles can work from it.

King (1952), in his roentgenographic study of pharyngeal growth, found that the position of the patient at the time the x-rays were made could affect the relative position of the atlas and, to a greater extent, the hyoid. He also reported in this paper that the distance between the hyoid bone and the cervical vertebrae was constant until puberty when the hyoid bone moved forward slightly.

Brodie (1955), in describing mouth opening, brought attention to the suprahyoid muscles which suspend the hyoid, larynx, pharynx, and tongue. Since these muscles are attached at or near the symphysis of the mandible, it follows that, should the hyoid bone passively follow the course of the chin, all of the above-named structures would fall back. This would shut off the airway. This is prevented by a shortening of the suprahyoids which thus indirectly aid in mouth opening. In 1959 he pointed out that as man attained an upright posture the head was balanced on the vertebral column by equal muscle tensions anterior and posterior to the occipital condyles. In the accomplishment of this the hyoid bone and larynx have been pressed into service as functional parts of the postural system of the body.

Material

The material for this study consisted of five longitudinal cephalometric series. Three of the series were derived from the Bolton Study, Western Reserve University. The remaining two series were obtained from the files of the Department of Orthodontics, University of Illinois. The age range in three of the series was from two to seventeen years, the fourth from three months to seventeen years, and the fifth from five to seventeen years. The series consisted of two females and three males. The x-rays were taken at spaced time intervals over the entire growth period, frontal and lateral exposures being made at the same time. Although the great majority of cases revealed that the teeth were closed when exposure was made, there were a few in which the mouth was open and others in which the position of the soft palate indicated that the individual was in the act of swallowing.

Since the five series studied showed a normal growth pattern as well as normal mandible movements, the authors included a case of a mandibular deformity resulting from rheumatoid arthritis, to compare the findings of the normal with the abnormal.

Method

Measurements were made on the

tracings of oriented headplates. The technique for taking and tracing these cephalometric films has been described by Broadbent and Brodie. Before measurements were taken several landmarks were recorded on the tracings. (Fig. 1) These included the following:

S—The center of sella turcica.
N—Nasion.
B—Bolton Point.
G—Genial tubercle — located on the posterior surface of the symphysis of the mandible.
H—Hyoid. The most superior point on the body of the hyoid bone.
Ptm—Pterygomaxillary junction.
Point A—as designated in this study, the most anterior point of the anterior tubercle of the atlas.
V—mid-point on each cervical vertebra as determined by measurement.

Lines were drawn connecting points G and H, H and B, and B and G. All of the legs and angles of this triangle were measured and recorded. On the first tracing of each series a vertical line was drawn through S and perpendicular to the Frankfort horizontal. This line was transferred to each succeeding tracing with the line SN superposed and S registered. This vertical line was employed as a reference point for measuring anterior and posterior distances. The tracings were superposed on the SN and vertical lines and the following points were located: B, G, H, A, and Ptm. Connecting the points B and H, G and H, resulted in a chevron-like series of lines lying at constantly lower levels (Figs. 2-3). The successive A and Ptm points were connected by straight lines. Ratios were taken between the lengths of B-H and G-H and both were related to B-G. The vertical distances were read between B, G, and H, and a line parallel to the Frankfort plane passing through S.

The measurements described above

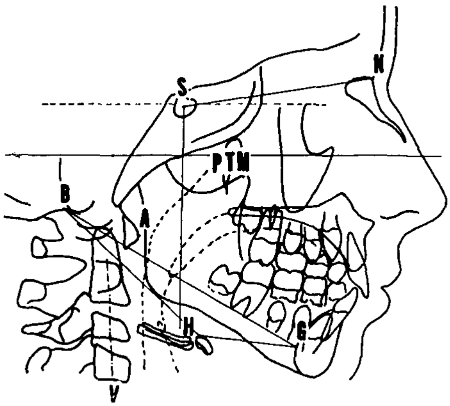

Fig. 1

did not exhibit as even and orderly progression of points as is found in cranial studies and an effort was therefore made to determine the cause of this more erratic behavior. It was felt that this might be attributable to variations in head posture.

Head position is reflected in the x-ray image in the cervical vertebrae and the relation of these bones to each other was examined in the following manner.

On each tracing the centers of the bodies of the 2nd, 3rd and 4th cervical vertebrae were determined by measurement. These centers were then connected and the most anterior point, i.e., the point nearest the vertical base line "S", was recorded on graph paper together with the point representing the body of the hyoid "H" (Fig. 4).

The "H" point was then raised to the same horizontal level as the vertebral point "V" as shown in (Fig. 5) and the "V" points and "H" points were connected by straight lines.

Findings

In each of the five series, three groups of measurements were taken. The first group was designated as skeletal growth measurements. This group included measurements from a line parallel to

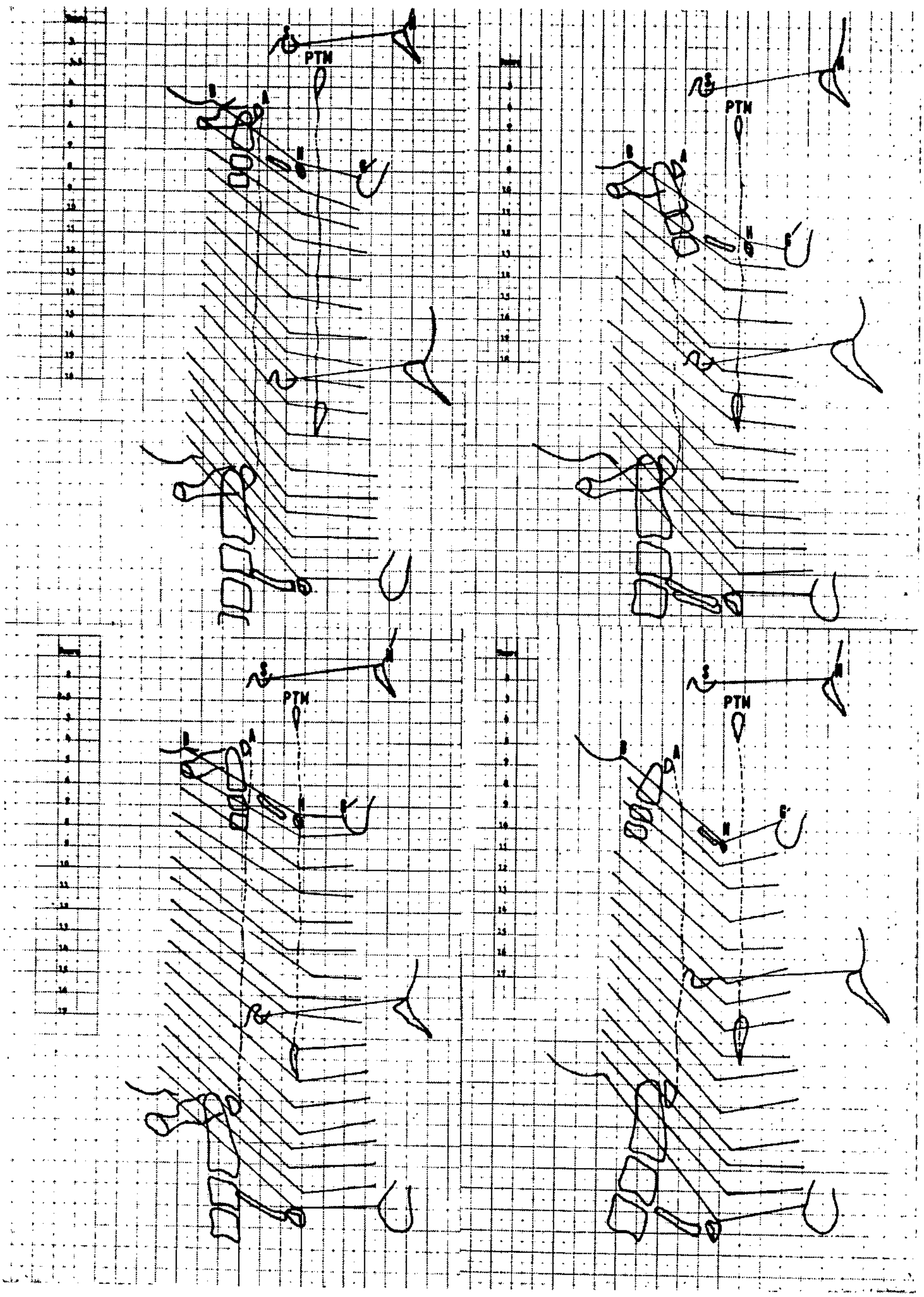

Fig. 2

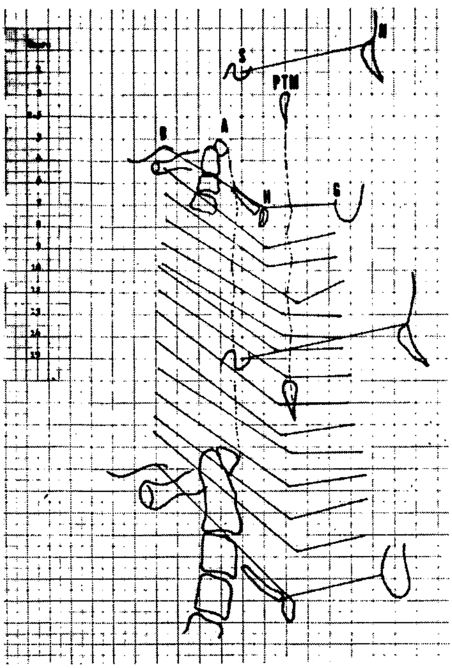

Fig. 3

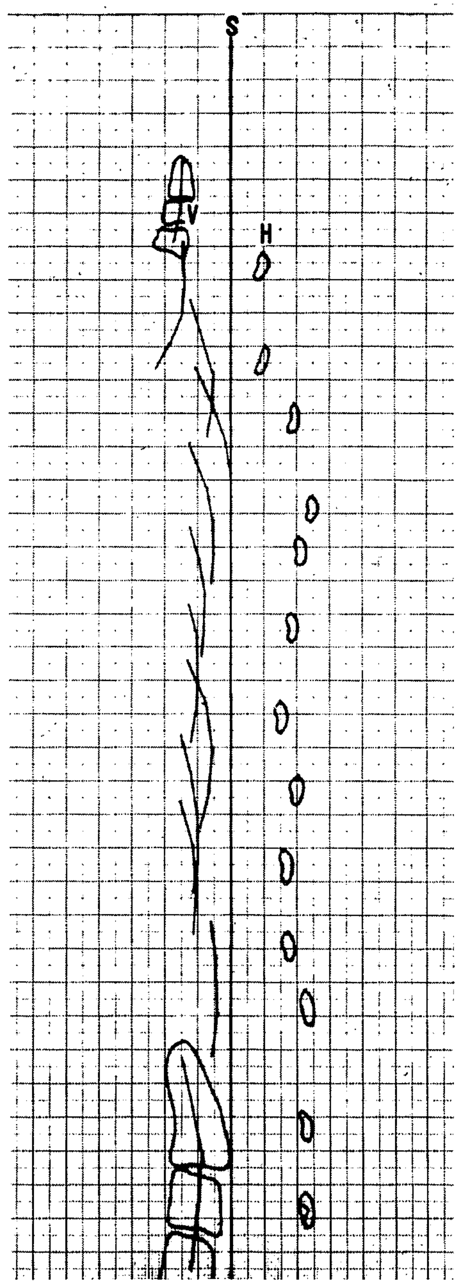

Fig. 4

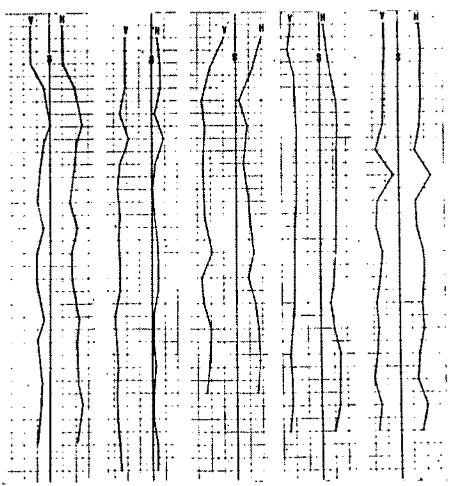

Fig. 5

TABLE I

SKELETAL GROWTH MEASUREMENTS

AGE	AB			DB			B-2357			B-2262			B-2035		
Years	SB	SH	SG	SB	SH	SG	SB	SH	SG	SB	SH	SG	SB	SH	SG
3	26	57	63	—	—	—	32	69	68	36	76	71	35	67	64
4	31	61	67	—	—	—	32	72	74	36	77	75	37	66	69
5	28	62	70	35	72	75	33	75	75	40	83	77	37	69	71
6	29	70	73	34	73	77	35	78	78	38	—	80	38	76	75
7	33	70	76	35	75	78	33	82	83	37	87	88	39	79	78
8	37	77	76	36	78	82	33	81	84	39	93	86	38	81	80
9	33	76	83	38	82	83	33	79	84	42	92	86	41	85	80
10	35	78	83	38	83	87	32	87	87	37	95	93	43	83	82
11	34	81	87	40	84	87	32	92	90	41	97	98	—	—	—
12	35	86	88	39	87	91	32	94	91	43	98	90	45	88	83
13	34	93	98	41	88	94	35	95	87	44	103	95	46	93	85
14	36	95	95	39	94	98	38	92	85	42	111	110	44	97	91
15	35	93	96	40	102	106	36	92	87	49	106	103	—	—	—
16	33	95	97	40	109	112	32	94	92	49	112	106	—	—	—
17	—	—	—	40	111	112	33	92	92	50	113	104	47	108	98

— Readings not obtainable.

the Frankfort plane passing through sella to points B, G, and H. The purpose of these measurements was to determine the relative rates of descent of the areas being investigated from a common plane of the head during growth (Table 1).

The distance from the S parallel to B was found to increase with age in four of the five series, in the fifth series B-2357, the distance tended to remain constant.

The distance from the S parallel to H was found to increase, in all five series, with age.

The distance from the S parallel to G was found to increase in all series, as did the distance from S parallel to H. These two last measurements were found to increase at about the same rate.

The second group of measurements was designated as muscle measurements since they were taken to represent the length of the muscles between their two points of attachment. One length was taken between B and H and the other between G and H.

The HG readings tended to increase with age in all five series. This increase was greater in some series than others, but all series showed an increase.

The HB readings also showed an increase with age which tended to be similar in all series. The measurements of the HB distance similarly revealed a constant increase. This measurement was invariably greater than that of HG in the first picture and maintained a larger size throughout the series (Table 2).

The third group of measurements was designated as angular to determine whether or not the growth of the two muscle measurements, namely, HG and HB, was so integrated that they formed a relatively stable angle with each other. This angle BHG was found to decrease with age in all series (Table 3). The special marks opposite certain of the readings in the table indicate either that the head was not properly positioned or that the patient was in the act of

TABLE II

MUSCLE MEASUREMENTS

Age Years	AB HG	AB HB	DB HG	DB HB	B-2357 HG	B-2357 HB	B-2262 HG	B-2262 HB	B-2035 HG	B-2035 HB
3	30	51	—	—	26	68	28	60	24	64
4	28	55	—	—	25	72	24	65	25	63
5	36	52	20	67	26	72	26	67	26	64
6	25	62	26	63	32	71	—	—	30	66
7	34	55	39	65	*23	83	28	71	29	71
8	36	59	34	61	34	73	30	76	31	70
9	37	58	38	61	35	73	31	75	33	72
10	33	63	35	68	32	82	33	76	32	72
11	38	63	35	66	33	85	33	77	—	—
12	39	67	32	76	35	86	33	77	35	75
13	41	70	40	68	37	89	38	81	31	79
14	41	75	37	75	41	83	33	90	32	86
15	43	75	35	84	41	84	36	87	—	—
16	42	74	35	88	35	90	36	90	—	—
17	40	78	36	91	40	84	43	89	44	86

* Patient had mouth open while taking x-ray.
— Readings not obtainable.

TABLE III

BHG ANGLE

AGE	AB	DB	B-2357	B-2262	B-2035
3	155	—	144	126	139
4	160	—	151	136	159
5	153	156	145	128	153
6	146	150	143	—	143
7	148	*118	147	138	144
8	141	144	144	123	142
9	137	137	149	127	136
10	144	145	137	126	149
11	140	145	131	135	—
12	136	148	129	125	138
13	133	143	126	122	130
14	136	138	131	127	128
15	130	140	133	135	—
16	132	135	133	128	—
17	132	130	136	120	123

* Patient had mouth open while taking x-ray.
— Readings not obtainable.

TABLE IV

CASE EXHIBITING MANDIBULAR DEFORMITY

AGE Yrs.	- Mos.	BHG ANGLE	SKELETAL GROWTH SG	SH	SB	MUSCULAR GROWTH HG	HB
4	6	157	67	64	37	25	56
5	0	154	70	65	37	29	49
12	6	107	76	85	38	28	57
15	9	88	75	87	40	38	49
16	7	90	76	84	36	36	49
22	5	89	77	88	39	35	50
26	8	84	78	88	37	36	52

swallowing as shown by the soft palate. It will be noted that these measurements do not fit well with the rest of the measurements.

Point A, which was used to designate the anterior tubercle of the atlas, was recorded on graph paper at each age. By connecting the points A, it was found to remain relatively stable throughout the age range studied in all series.

The Ptm points were also recorded, as were points A; it was found that Ptm remained stable throughout the age range studied.

The behavior of the hyoid bone in response to flexion of the cervical vertebrae shows that the hyoid is relatively stable in its relationship to the cervical vertebrae. It may be said that any movement of the cervical vertebrae will be exhibited by a corresponding movement of the hyoid bone.

Findings in Mandibular Deformity

The same readings were taken in this series as those taken from the normal series (Table 4).

The SB readings showed little or no change from 4.6 years to 26.8 years. The SH readings showed a small increase with age but not as great as it appeared in the normal series. The SG readings showed an increase but, again, this increase was small as compared with the normal series.

The distances from H to B and H to G which are taken to indicate the lengths of muscles revealed the following: The HG readings increased with age but the increase was not as large as in the normal series. The HB readings were found to decrease with age which was the reverse of what occurred in the normal series. The BHG angle which had been shown to decrease in the normal series showed a much greater decrease with age in this patient (Fig. 6).

Points A and Ptm were recorded and showed stability throughout the series.

The difference in behavior of the hyoid bone in response to the severe vertical flexure was very striking. Whereas in the normal series this point (H) had always remained ventral to the vertical S line, in this patient it was found to have crossed this S line and to have almost reached the V line. After 15 years of age it remained parallel with the V line. In spite of these extreme changes the area for the airway was maintained as indicated by the vertical lines to the right of each age stage in the illustration. These represent the shortest distances between the hyoid line and the arc representing the anterior surfaces of the second, third and fourth vertebrae.

Discussion

Although it could hardly be expected that a bone whose position is almost

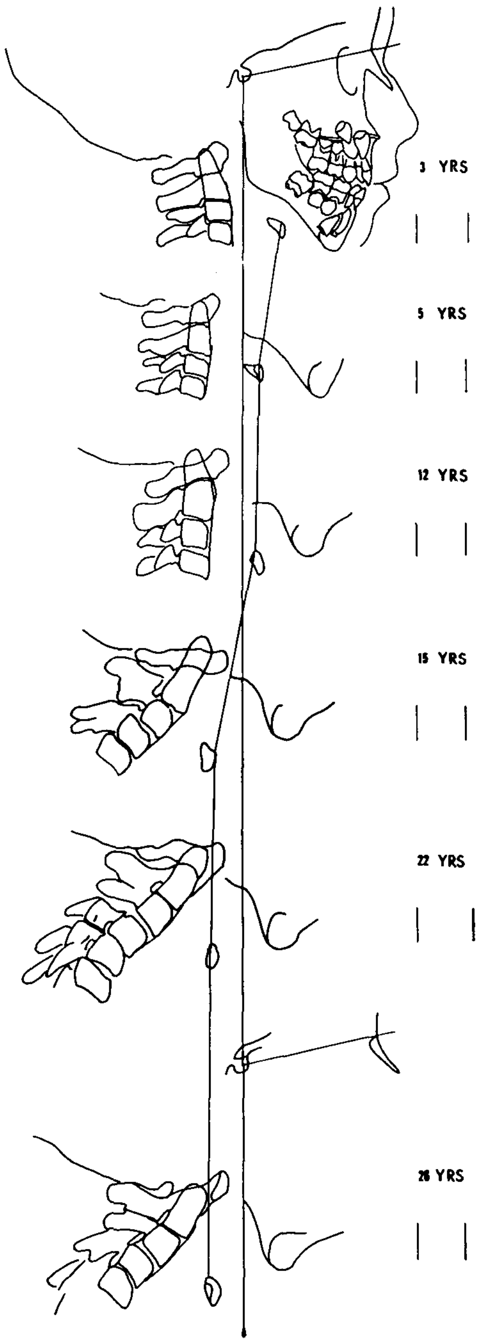

Fig. 6

entirely controlled by musculature would show the same degree of stability of those of the head skeleton, it is surprising to note how steady it is. It must be realized that films upon which the study was made were exposed under varying conditions and for purposes other than this study. Flexions of the head, tenseness of the subject, functions such as swallowing would not affect bones connected by sutures but might conceivably alter one suspended from them.

Viewed in the light of the nature of this suspension, the wide variation seen in the position of the bone among a group of individuals is to be expected. With points of suspensions bilaterally on the cranial base and almost at the midline of the mandible, it follows that any differences in the relative locations of these three points would result in relative changes in the hyoid bone, at least anteroposteriorly. Since the anterior or mandibular point shows the widest range of variation of any in the head, the variation in the position of the hyoid is easily explained. In contrast to the variation in its anteroposterior position is its stability superoinferiorly. Both in the growing individual and in the group it maintains a position at a level between the bottom of the third and top of the fourth cervical vertebrae.

It should be reiterated that the hyoid bone in man has assumed additional functions over those demanded in other species. With the marked flexion of the cranial base and the forward migration of foramen magnum which accompanied the gaining of an upright posture, the larynx and trachea were no longer held away from the upper respiratory tract by gravity. Patency of the airway could only be maintained by those muscles lying anteriorly to the hyoid bone, viz., geniohyoids and mylohyoids. This function was greatly aided by the growth of the chin as pointed out by Weidenreich and others.

Strong supporting evidence for these concepts is given by the pathological case shown in this study. Failure of the mandibular symphysis to progress downward and forward with growth led to a gradual decrease in the distance between the posterior and anterior points of suspension. This resulted in a corresponding drop in the hyoid level and a decreasing angle between the muscles running to the bone from in front and back. But the nature of this drop points to another important consideration.

Since the growth arrest affected the location of only the mandibular point, it might be expected that the hyoid bone would not only drop but would move posteriorly as well. The serial tracings reveal that this did happen but, had the new position been dictated by only the resting tonus of the muscles, it would have been even more posterior and would have progressed as the deformity worsened. This would have resulted in blocking the airway.

Measurements of the airway taken from the x-rays revealed a gradual narrowing of the airway between the fifth and twelfth year. Between the twelfth and fifteenth year there was rapid narrowing, but from the latter year it remained stable as shown in the diagram. Coincident with this, the contraction of the anterior suprahyoids began to increase until a pronounced swelling appeared between the mandibular symphysis and the hyoid. This was interpreted as an involuntary effort to hold the larynx forward and maintain breathing space.

The strict proportionality that is maintained among the parts of the head skeleton during its growth was pointed out by Brodie in 1941. That work showed that, in spite of large increments of increase in such areas as the posterior cranial base and the mandible, the interval between them, viz., the pharyngeal area, showed little or no enlargement from birth onward. Thus the food and air channels were kept constant in size throughout growth. Yet these two channels are not in function simultaneously.

This is not to say that pharyngeal structures are not subject to the same degree of variation as are any other parts. Suspended as they are, they are dependent upon the relative location of their points of suspension, and marked differences in their resting and functional positions may be seen in any group of persons. Their positions in the individual, however, are remarkably stable.

Summary

This investigation was based on a study of five longitudinal cephalometric x-ray series of individuals exhibiting normal growth patterns and one series exhibiting a mandibular deformity resulting from rheumatoid arthritis. The age range in three series was from two to seventeen years, the fourth from three months to seventeen years, and the fifth from five to seventeen years. The age range of the series exhibiting the mandibular deformity was from four to twenty-six years.

The headplates were traced and the following points were recorded: Bolton Point (B), the most superior point on the hyoid body (H), genial tubercle on the mandibular symphysis (G), center of sella turcica (S), Nasion (N), the most anterior point on the anterior tubercle of the atlas (A), pterygomaxillary fissure (Ptm) and the centers of the second, third and fourth cervical vertebrae (V). These points were recorded to determine the growth behavior of the hyoid bone by linear and angular measurements.

The distances between certain of these points, viz., S to B, S to H, S to G, were measured to evaluate skeletal

growth behavior and the distances, BH and GH, to determine the increase in muscle lengths. The angle BHG was measured to note the change, if any, in the spatial position of H.

Straight lines connecting the successive levels of the points A and Ptm revealed that both followed a straight downward course. Since these are the posterior and anterior points of suspension of the pharynx, their stability indicates lack of change in this dimension of the pharynx.

The abnormal case revealed that the growth disturbance did not affect the distance between A and Ptm but that the hyoid bone took an increasingly posterior position until checked by contraction of its anterior suspensory muscles.

Conclusions

1. The hyoid bone is positioned superoinferiorly at a level opposite the lower portion of the third and upper portion of the fourth vertebrae. Its position anteroposteriorly depends on the relative length of those muscles running to it from the base of the cranium bilaterally and from the region of the mandibular symphysis. It is thus controlled by a three point suspension. Its position is probably further modified by the pharyngeal and infrahyoid muscles and by gravity acting upon the larynx.

2. During the period of growth the hyoid descends as the cervical vertebrae increase their height and the posterior cranial base and the mandible descend and move away from each other. This descent, however, is of such a nature that the relative position of the bone does not change.

3. In the movements of the head and in those cases in which a growth arrest or accident results in an abnormal position of one of its points of suspension, the bone is shifted accordingly, but such shifting is limited by a compensatory muscle reaction which insures the patency of the airway.

808 S. Wood St.

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