A Radiographic Study of Tongue Posture at Rest and During the Phonation of /s/ in Class III Malocclusion

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It has long been known that orodental morphology has a great influence on physiologic functions in the area of the oral cavity. We also know that functional compensations can be demonstrated for variations in the orodental morphology so that the physiologic needs of the organism are met in as productive a way as possible. We have been brought to realize, however, that there are limitations to this adaptability of the individual to orodental morphopathology in the performance of physiologic function.

One of the most difficult types of orodental morphopathologic relationships is the Angle Class III malocclusion. In this dental/skeletal relationship many compensating alterations of function are seen due to the anatomic problems that must be overcome for the individual to successfully accomplish his physiologic tasks. The tongue is probably the most active functional part of the oropharyngeal system and it is directly influenced by any modification in the orodental environment, especially of the mandible. The tongue's most complex physiologic assignment appears to be its role as an articulator in ongoing human speech.

LITERATURE REVIEW

Relatively little has been said in the literature about the interrelations of Class III malocclusion, the tongue, and speech production. This is probably due to the complexity of these problems, the relative difficulty in getting objective data, and the historic lack of communication between the various disciplines whose interests overlap in this most complex area.

Man's ability to produce articulate speech is dependent upon the integrity of numerous neurological, physiological and physical mechanisms. The findings of several studies appear to indicate that the dental environment influences lingual behavior and consequently the quality of articulated phonemes.

Fairbanks and Lantner[6] found no significant relationship between their speech ratings and class of malocclusion observed. However, in a comparison among the three classes of malocclusion studied, the tendency was reported for the subjects with Class I malocclusions to be placed in the category of superior speaker while the subjects with Angle Class II and Angle Class III malocclusions were placed more frequently in the category of inferior speaker. In another study of lingual-dental factors related to speech behavior, Snow found that /s/ was the most frequently misarticulated phoneme.[13]

It should be noted that in all the studies reported thus far some speakers were found to have normal articulation even in the presence of dental and skeletal malrelationships. In acknowledging the occurrence of this phenomenon Benediktsson[1] pointed out that normal articulation in the presence of dental abnormality may be accomplished by means of certain compensa-

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tory movements of the dental and speech anatomy. Specifically, she found that in her subjects with malposed incisors normal /s/ production could be accomplished through compensatory movements of the mandible and the tongue which resulted in a more normal relationship between the tongue tip and the dentition. In a later study of /s/ articulation and variations in the incisal relationship, Weinberg found that certain compensatory adjustments of the mandible and the tongue resulted in normal /s/ articulation.[16] He also observed that a defective /s/ was produced when the tongue tip was positioned anteriorly to the lower incisors. Thus, these two studies seem to indicate that certain compensatory movements of the mandible and/or the tongue may result in normal /s/ articulation in the presence of malocclusion.

Blythe[3] found a close relationship between Class II, Division 1 malocclusion and interdental lisping. He says, "Although the tongue is usually bi-laterally symmetrical and emission of air centralized, the tongue is incorrectly positioned vertically, anteroposteriorly or a combination of both." He also found an association between Class II, Division 2 malocclusion and lateral lisping. Powers[12] stated that in a lateral lisp the tongue tip is pressed against the upper central incisors or the alveolar ridge. The air stream cannot be emitted through a central groove, but is divided and escapes at the sides of the mouth.

In a later and more definitive study completed by Subtelny, Mestre and Subtelny[14] in 1964, the relationship between Class II, Division 1 malocclusion and articulatory production of the /s/ phoneme was explored. In this study, patterns of lingual behavior at rest and during the production of the /s/ phoneme were objectively quantified by means of cephalometric roentgenography. Three groups of speakers were studied. One group consisted of normal speakers with normal occlusion. The second group consisted of subjects with normal /s/ production but with Class II, Division 1 malocclusion. Comprising the third group were subjects with defective /s/ production in the presence of a Class II, Division 1 malocclusion. An analysis of the results showed that significantly different articulatory patterns existed among the three groups of subjects. These researchers found that normal speakers with normal occlusion during /s/ production demonstrated the following articulatory adjustments: 1) the incisors assumed a near edge-to-edge relationship which was accomplished by a slight protrusion of the mandible, 2) the tongue tip was positioned posterior to the lower incisors, 3) the molars were slightly separated, 4) the position of the blade of the tongue was consistently related to the palate and alveolar process, 5) the tongue tip varied widely in its vertical position, and 6) the hyoid bone elevated about five millimeters during function. The only significantly different articulatory adjustment performed by normal speakers with Class II, Division 1 malocclusion, not seen in subjects with normal occlusion, was a retrusion of the tongue relative to the upper incisors. As a result of this maneuver, the tongue tip was maintained in a fairly normal position relative to the retruded mandible.

In a comparison of normal and defective speakers both with Class II, Division 1 malocclusions, Subtelny, Mestre and Subtelny found that the articulatory adjustments of defective speakers were significantly different from those performed by normal speakers. Specifically, the data obtained for defective speakers indicated that: 1) the tongue tip protruded beyond the lower incisors approaching the lingual surfaces of the protruded upper incisors, 2) the dis-

tance between the upper and lower incisors was greater than in normal subjects both at rest and during /s/ production, and 3) the hyoid bone position was lower in defective speakers.

The results of this study when viewed in relation to previous reports appear to indicate that the dental environment does greatly influence speech behavior. In this vein the results of several investigations corroborate the significance of compensatory adjustments in allowing for the attainment of normal articulation in the presence of dental abnormality. In the case of Class II malocclusion the nature of several of the features of different compensatory patterns utilized to achieve normal articulation has been clearly delineated.

It should be noted, however, that there has been little or no research concerning the possible effect of other types of malocclusions on speech behavior and associated compensatory posturing of the articulators. This paucity of data becomes particularly apparent in examining the literature relative to Angle Class III malocclusion.

While discussing Class III malocclusions on the basis of his clinical experience, Bloomer[2] stated that this problem "may cause no difficulty in speech if the condition is relatively mild. Even a considerable deformity may cause no obvious articulatory defect if the lips and tongue can adapt to the structural handicap. Frequently, however, individuals who have this type of malocclusion have a tongue posture which is habitually low and somewhat flaccid so that a constriction of the linguo-alveolar valve necessary for sibilants is not effectively produced. A further complication is often found in the relative protraction of the mandibular arch, so that the tongue is habitually brought into contact with the occlusal edges of the maxillary teeth instead of being brought into the proper contact with the alveolar arch and the linguodental surfaces."

These clinical observations should be investigated quantitatively to establish their experimental validity. Recently, while reviewing interdisciplinary research needs in speech pathology and dentistry, Bzoch[5] called for exploratory probes into the nature of the compensatory speech adjustments associated with a variety of types of malocclusions. Thus, research concerned with the lingual-dental patterns associated with Class III malocclusions may lead to a better understanding of articulatory defects associated with this skeletal pattern and of the attempt at functional compensation for this anatomical problem.

Methods and Materials

In this investigation individuals who presented a Class III malocclusion were examined radiographically and acoustically in an attempt to determine the adaptation, if any, of the tongue in rest posture and in speech function, especially in production of the phoneme /s/, to the altered orodental environment presented by this type of malocclusion.

All subjects included in the experimental group for this study were obtained from two private orthodontic practices and all demonstrated an Angle Class III malocclusion characterized by a full anterior crossbite. No screening was done to determine the nature of the malocclusion, that is, whether it was a skeletal or a dental problem, or whether the mandibular prognathism was due to a variation of the maxilla, the mandible, or both. No severe anteroposterior discrepancies, however, were included in this sample. Speech characteristics were not considered in assessing suitabiilty of individuals as subjects.

The experimental group consisted of

twelve individuals, seven males and five females. The mean age was 13 years. This age of experimental subjects was selected so the observed results could be statistically compared with the normal data established by Subtelny, Mestre and Subtelny for lingual function and to the normal data established by Downs, Steiner and Lande for skeletal and dental relationships. Subjects were excluded who reported a history of neurological pathology. This requirement was considered necessary to rule out the possible occurrence of auditory and/or lingual neurological pathology which may have an effect on articulatory ability, as neurological deficiencies of the oral musculature may be associated with defective articulation.

A variety of clinical tests designed by Johnston, Darley and Spriestersbach[9] to assess the mobility of the oral muscular functions was performed. The function was evaluated by the pucker-smile maneuver performed as rapidly as possible. Functioning of the mandible was assessed by protrusion, maximum jaw opening, and by evaluation of the rapid chewing procedure. To assess lingual function the subject was required to protrude his tongue, curl it toward the chin, elevate it toward the nose and to touch the palate. An assessment of tongue mobility was performed by judging the rate of lateralization from one corner of the mouth to the other as described by Johnson, Darley and Spriestersbach. Oral diadochokinesis was tested to evaluate the function of the articulators during the performance of the speech task. The subject was required to repeat the nonsense word /pʌtʌkʌ/ as rapidly as possible. To qualify for participation in this study subjects were required to perform these tasks according to the normal clinical standards that have been established by Johnson et al.

Finally, all subjects were required to have normal hearing in both ears. Normal hearing was defined as a response to pure tones elicited at twenty-five decibel intensity level for the following frequencies: 250Hz, 500 Hz, 1000 Hz, 2000Hz, 3000Hz, 4000Hz and 6000Hz. This screening test was performed by means of a Bell-tone 10-D portable audiometer.

Cephalometric Analysis

The assessment of tongue, dental, jaw and hyoid posture was made from lateral cephalometric radiographs taken in the standardized accepted manner with the addition of two factors. A millimeter scale placed on the nosepiece of the cephalometric headholder in the midsagittal plane was exposed on the films for adjustment of linear observations to correct for the differential enlargement of the image from subject to subject. To provide more exact tongue visibility on the radiographs, a radiopaque contrast paste was applied to the tongue along its approximate clinical dorsal midline, over the tip, and onto the approximate clinical ventral midline to the lingual frenum. The radiopaque paste utilized was Esophotrast Barium Cream.* It is easily applied in a narrow dimension and its minimum bulk will not interfere with the movements of the tongue. It is somewhat adhesive and retains its integrity for approximately two swallows.

The lateral cephalometric radiographs were obtained with the patient's head oriented in the Frankfort horizontal plane. The films were exposed with the patient's teeth in full occlusion, at rest, and during the sustained phonation of the phoneme /s/. These films were of diagnostic quality and provided reliable definition of the structures to be studied. The choice of the phoneme /s/ was made so the observed results

*Barnes-Hind Diagnostics

could be compared with those published by Subtelny, Mestre and Subtelny who have indicated the phoneme /s/ is phonetically classified as a continuant sound which lends itself well to sustained production.

The cephalometric radiographs were analyzed according to the method developed by the same authors, with minor modifications, for statistical appraisal of the tongue, lips, mandible and hyoid bone. In this analytical method the following reference points, lines and angles and measurements were utilized, as illustrated in Figures 1, 2 and 3.

From these cephalometric observations, mean values, standard deviations and standard errors were computed. The means were compared with the similar data obtained by Subtelny, Mestre and Subtelny on thirty normal speakers with normal occlusions. The parametric Student's t-test for unequal numbers of subjects was utilized for evaluation of significant differences between mean values. As it was thought useful to know the nature of the skeletal or dentoalveolar discrepancy in the Class III malocclusions that made up this sample, mean values for the skeletal relationships were compared with data previously published by Downs, Steiner and Lande.

Speech

The subject's articulatory ability was assessed by means of the Templin-Darley Screening Test of Articulation.[15] In addition, a two minute spontaneous speech sample was elicited by discussing a topic of interest with the subject. Both speech samples were tape recorded for purposes of analyzing the quality of /s/ production. The procedure used for this speech analysis was adopted from that of Weinberg;[16] a scale from one to four was constructed wherein an assignment of 1 indicated normal speech production, 2 a mild distortion, 3 a moderate distortion, and 4 indicated a severe distortion of speech.

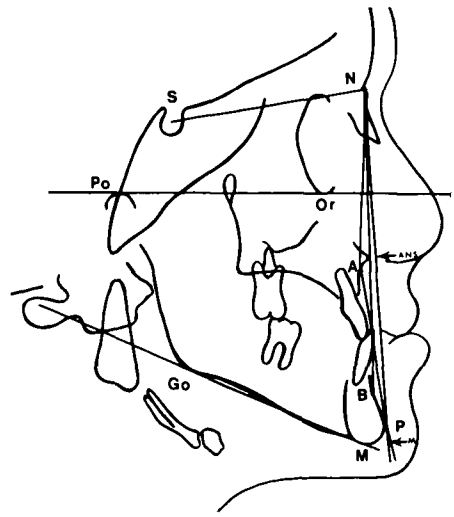

Fig. 1 Downs' facial, convexity and mandibular plane angles; the angles SNA, SNB, ANB and the angle formed by NA and Frankfort. UFH/TFH, ratio of the upper facial height, measured along the facial plane from nasion to the projection of the anterior nasal spine, to the total facial height, measured along the facial plane from nasion to the projection of menton.

Results

The results obtained from the first measure, the Templin-Darley test, showed that four speakers demonstrated normal speech in the production of single words. The remaining eight subjects were observed to have some misarticulations. Each of these eight speakers distorted one or more of the sibilant class of phonemes. Item analysis for single words showed that eleven of the twelve speakers distorted the /s/ phonemes.

Production of the /s/ phoneme was also assessed during spontaneous speech on a scale ranging from one to four as described above. The result of the analysis for the spontaneous speech sample showed that eleven of the twelve Class III subjects distorted the /s/ phoneme from a mild to moder-

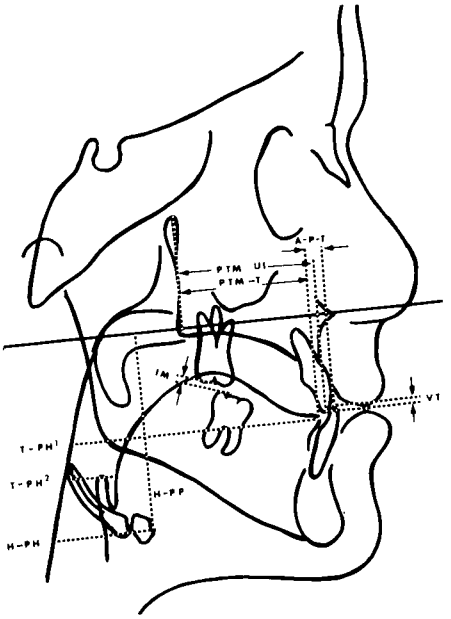

Fig. 2 Cephalometric tracing illustrating the measurements described. Horizontal measures of tongue position. APT, anteroposterior position of the tongue tip relative to the lower incisor, dimension between tongue tip reference (TTR) and lower incisor reference (LIR) lines measured parallel to the palatal plane. Plus and minus measurements, respectively, indicating tongue tip positions anterior and posterior to the lower incisal edge. T-PH[1], posterior outline of the tongue to the posterior pharyngeal wall on the lingual reference line. T-PH[2], shortest dimension between tongue and pharyngeal wall. PTM-T, tongue tip to point of intersection between PTM line and lingual reference (LR) lines. PTM-T/PTM-UIR, tongue tip in proportion to maxillary length; PTM to upper incisal edge divided by dimension PTM to tongue tip.

Vertical measures of tongue position. VT, vertical position of the tongue tip relative to the lower incisor; dimension between point of intersection of lingual reference (LR) and lower incisal reference (LIR) lines and the lower incisor. Plus and minus measurements, respectively, indicating positions of the tongue tip above and below the lower incisal edge. MAX., maximum constriction; shortest distance between tongue and alveolar ridge or teeth during /s/ production.

Hyoid measurements. H-PH, anteroposterior position of the hyoid bone; between point H and the posterior pharyngeal wall, measured parallel to the palatal plane. H-PP, vertical position of the hyoid; dimension from point H to palatal plane.

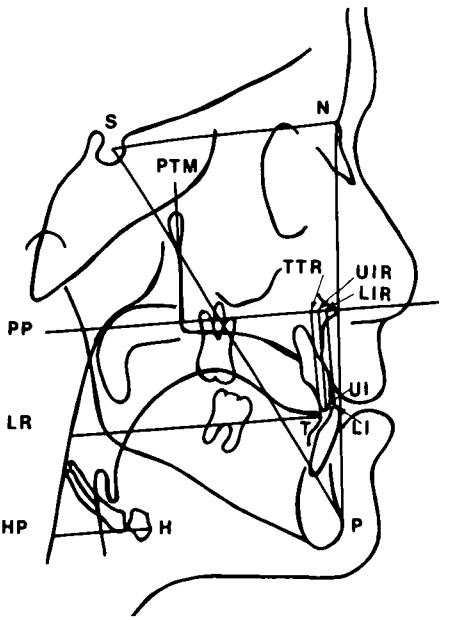

Fig. 3 Cephalometric tracing illustrating reference points, lines, and angles: H, anterior superiormost point of the body of the hyoid; T, anterior superiormost point of the tongue tip; LI, lower incisor edge; UI, upper incisor edge; PP, palatal plane; LR, lingual reference-tongue tip to posterior pharyngeal wall, parallel to palatal plane; TTR, tongue-tip reference-perpendicular from palatal plane to tongue tip; LIR, lower incisor reference-perpendicular from palatal plane to lower incisor edge; UIR, upper incisor reference-perpendicular from palatal plane to upper incisor edge; PTM, perpendicular to palatal plane bisecting pterygomaxillary fissure; HP, hyoid pharyngeal-point H to posterior pharyngeal wall, parallel to palatal plane.

Mandibular measurements. SNP, an increase or decrease in angle SNP from rest to the position assumed during /s/ production, respectively, indicating protrusion or retrusion of the mandible. NSP, an increase or decrease in angle NSP indicating depression or elevation of the mandible. IM, intermolar; dimension between the occlusal surfaces of the upper and lower molars. I-I, interincisal; dimension between upper and lower incisal edges.

TABLE I

Results of comparative cephalometric analysis of 12 Angle Class III individuals and previously published norms

Measurement	*Normal Occlusion* Mean	*Class III* Mean
Facial Angle (N-P-/FH)	87.8°	88.9°
Lande's Angle (N-A/FH)	88.0°	86.5°
Angle of Convexity (N-A-P)	0.0°	—4.3°
S-N-A	80.0°	80.2°
S-N-B	78.0°	81.5°
A-N-B	2.8°	—1.3°
Mandibular Plane (Mand. pl/FH)	21.9°	28.4°
UFH/TFH (N-ANS/N-M)	43.0%	42.5%

ate degree. Specifically, /s/ production in five subjects was mildly distorted while six subjects were found to have moderate distortion of the /s/ phoneme. Thus, only one of the speakers in this study was rated as a normal speaker. The factors contributing to the high incidence of distortion among Class III subjects were examined by means of the lateral cephalometric X-ray analysis with the features of lingual-dental posture demonstrated in the sustained production of the phoneme /s/.

The mean values for the observations utilized in the analysis of skeletal relationships with the established normal means for the same parameters can be seen in Table I. We can infer from this comparison that according to the norm values of Downs and Lande, on the average, the mandibles in this sample were essentially normal, but tended toward the high side of the normal range; the maxillae were also normal, but showed a tendency toward the low side of the normal range. Thus, the somewhat large mandibles in combination with the relatively small maxillae, although both jaws remained essentially in the normal range, resulted in a relatively concave facial skeletal profile.

According to the Steiner analysis, however, the mandibles in this sample appear to be abnormally forward, outside of the normal range, while the maxillae were right on the mean position. This also results in a concave skeletal profile.

The mandibular plane was abnormally steep, outside the range of normal, but the percentage of the upper facial height to total facial height was essentially normal.

The old cephalometric question of validity of planes of reference rears its ugly head here again. The data offer two different conclusions according to the plane of reference chosen. Since it has been shown that Frankfort horizontal gives a more reliable indication of true skeletal profile posture, our conclusion is that, on the average, this sample illustrated essentially normal but relatively large mandibles and essentially normal but relatively small maxillae giving a resultant Class III skeletal profile.

Comparison of the observed data and the mean values established by Subtelny et al. for lingual-dental posture, at rest, reveal (Table II): a) The horizontal measures of tongue posture indicated a significant difference between the Class III and the normal subjects in the distance between the tongue tip and the point of intersection between the PTM line and the lingual reference line. The distance between these lines may be viewed as a horizontal measure of tongue length. Analysis shows the mean distance was significantly less in the Class III subjects than in subjects with normal occlusions. Therefore, it appears that, at rest, Class III subjects retruded their tongues in relation to the cephalometric TT/PTM reference points. b) Vertical measures of tongue position disclosed no significant difference betweeen the Class III sample and the established norms. c) Mandibular measurements showed no

TABLE II

Results of comparative cephalometric analyses for 30 normal speakers with normal occlusion and 8 speakers with Class III malocclusion

Measurement		*Normal Occlusion*			*Class III*			
		Mean	SD	SE	Mean	SD	SE	t
Angle NSP	Rest	64.82°	2.94	0.54	64.68°	3.03	1.07	.12
	/s/	64.17°	3.22	0.59	67.50°	5.52	1.95	2.21*
Angle SNP	Rest	80.32°	3.20	0.58	82.56°	4.53	1.60	1.61
	/s/	81.50°	3.99	0.73	82.00°	4.74	1.68	.30
Inter-incisal	Rest	3.60mm	1.33	0.24	2.20mm	4.23	1.60	.71
Dimension	/s/	2.12mm	1.34	0.25	1.20mm	3.27	1.16	1.01
Inter-molar	Rest	1.63mm	1.53		1.64mm	1.53	0.57	.01
Dimension	/s/	1.25mm	0.79		1.07mm	1.76	0.62	.41
Lip Aperture	Rest	2.63mm	3.70	0.68	3.79mm	4.76	1.95	.74
	/s/	8.35mm	2.72	0.50	9.41mm	5.94	2.10	.75
Vertical Measure								
Tongue tip to	Rest	0.72mm	2.44	0.45	—0.09mm	2.12	0.75	.85
Lower incisor	/s/	0.67mm	1.28	0.23	0.52mm	2.49	0.88	.24
Maximum constriction	/s/	2.20mm	1.44		1.79mm	1.33	0.47	.51
Horizontal Measure								
Tongue tip to	Rest	—3.08mm	3.06	0.56	—4.92mm	2.92	1.03	1.52
Lower incisor	/s/	—3.33mm	1.64	0.03	—4.73mm	1.67	0.59	2.13*
Tongue tip to	Rest	51.32mm	4.16	0.76	39.51mm	4.31	1.52	7.08**
PTM	/s/	51.62mm	4.12	0.75	40.04mm	3.10	1.10	7.38**
PTM-Tongue tip / PTM-Upper incisor		0.90	0.042	0.008	.93	.02	.01	.05
Tongue-Pharynx on Lingual reference	Rest	14.93mm	6.11	1.14	13.44mm	4.87	1.72	.64
	/s/	14.07mm	5.15	0.94	16.28mm	4.93	1.74	1.09
Tongue-Pharynx Shortest Dimension	Rest	9.52mm	4.39		10.06mm	2.57	0.90	.33
	/s/	10.12mm	3.99	0.73	12.99mm	3.68	1.30	1.83
Hyoid-Pharyngeal Wall	Rest	32.75mm	5.67	1.05	26.91mm	3.65	1.29	2.75**
	/s/	33.52mm	5.87	1.09	31.00mm	7.85	2.78	1.00
Hyoid-Palatal Plane	Rest	67.22mm	9.58	1.75	54.83mm	7.31	2.58	3.39**
	/s/	62.98mm	8.66	1.58	51.97mm	9.74	3.45	3.12**

*Significant at the 5% level
**Significant at the 1% level.

significant difference between the two groups. d) Hyoid measurements showed significant differences at the 1% level in both vertical and horizontal positions of the hyoid bone body. It was seen that the distance between the hyoid bone and the palatal plane was significantly less in the Class III subjects than in the normal subjects. This finding suggests that the hyoid bone was elevated to a greater degree in the Class III patients. The anteroposterior position of the hyoid bone with respect to the posterior pharyngeal wall was

also significantly less in the Class III group compared with the control group. Since hyoid elevation and retrusion are associated with tongue retrusion, these observations on hyoid position are supportive of the tongue tip-PTM measurement which also indicated that the lingual posture of Class III subjects was significantly retruded during rest.

Comparison of the observed data and the norms established by Subtelny et al. for lingual-dental posture during sustained phonation of phoneme /s/ yielded the following information: a) Horizontal measures of tongue posture indicate a significant difference in the position of the tongue tip in relation to the lower incisor as indicated by an increased distance between the tongue tip reference and the lower incisor reference line; and in the position of the tongue tip in relation to PTM as demonstrated by a decreased distance between the intersection of the PTM line with the lingual reference line and the tongue tip, point T. b) Vertical measures of tongue position showed no significant differences between the Class III group and the control group. c) Mandibular measurements revealed a significant difference between the groups in the observed angle NSP. An increased angle NSP in the Class III group during the phonation of the phoneme /s/ indicates a relatively greater depression of the mandible in the production of this phoneme in the Class III group. d) Hyoid measurements illustrated, as in the rest film, a decreased distance between the hyoid body and the palatal plane in the Class III group indicative of a more elevated hyoid body than seen in the control group.

Clinical evaluation of the experimental group revealed that five of the twelve subjects demonstrated posterior crossbite.

Discussion

It was subjectively noted that, on the average, there seemed to be a lower than normal tongue posture than is generally seen in cephalometric radiographs. No objective measure of this tongue posture was made, however. Also, clinically, some of the tongues studied appeared to be relatively "large."

Since five of the twelve experimental subjects demonstrated a posterior crossbite, our curiosity is aroused concerning the possible relationship of these observations. Does a low tongue posture environment, where the tongue may have a decreased influence on the maxilla, have any bearing on the development of the maxilla in its width?

It is the contention of some that in cases presenting relatively large tongues, that is, tongues overflowing the confines of the mandibular arch with the presence of a posterior crossbite, maxillary expansion therapy to increase maxillary width and therefore increase total oral volume may be useful in providing more space for the tongue to occupy. Since the tongue is thereby rendered relatively less large, this procedure may be of assistance in reducing some of the problems associated with a relatively large tongue. Observation of the cephalometric radiographs of these cases indicated that a relatively large tongue clinically often did not appear radiographically to completely fill the oral cavity space potentially available to it. Perhaps the low tongue posture limits the adaptation capabilities of relatively large tongues to occupy needed "lebensraum," so to speak, vertically. If this is the case, palatal expansion procedures may do little to aid relatively large tongues in cases where their posture is abnormally low.

The findings of this study bear importantly upon a number of clinical hypotheses that have been advanced con-

cerning the speech behavior of speakers with Class III malocclusions. On the basis of his informal observations Bloomer stated that, in regard to the ability to produce correct speech, the Class III dental environment "may cause no difficulty if the condition is relatively mild." In the present investigation no subjects were diagnosed as having severe Class III malocclusions. Yet, eleven of the twelve subjects studied manifested some degree of sibilant distortion. This finding suggests that the incidence of articulatory deficiency in the presence of Class III malocclusion may be substantially higher than is presently estimated. Indeed, future studies may show that this malocclusion is a greater source of defective speech than many other abnormal dental environments. This problem should be investigated further in comparative studies of the incidence and characteristics of articulatory defects across the spectrum of the various types of malocclusion.

A second clinical inference made by Bloomer is that no speech defect will result if the lips and tongue are able to adapt to the dental environment. Though this assumption may be valid, the results of the present investigation showed that only one of the twelve subjects with Class III malocclusions was able to achieve normal /s/ production through compensatory adjustment of the articulators. The data demonstrated that no significant difference existed in lip aperture among Class III speakers and normal control subjects. However, it is important to recall that significant differences were found in certain lingual measurements between the two groups of speakers. The data obtained from measurement of the tongue tip to the lower incisor (TT-LIR), tongue tip to PTM (TT-PTM), and hyoid to palatal plane (H-PP) suggest that the tongue is significantly retruded in Class III speakers during /s/ production. Although these three measurements are indicative of tongue retrusion in Class III speakers, the ratio PTM-TT/PTM-UIR was not found to differ significantly from normal subjects. Since this ratio measure relates the tongue tip to the upper incisor, it appears that the Class III speakers achieved correct tongue-tip placement, anteroposteriorly, during /s/ production with respect to the maxillary incisors. This observation was further supported by the measurement of maximum constriction, another measure of anterior tongue placement. The fact that Class III and normal speakers did not differ significantly in this factor also demonstrates that the anterior lingual posture was appropriate for the correct articulation of the /s/ phoneme.

Findings here illustrate the degree of lingual accommodation and compensation in /s/ production for the anterior crossbite characteristic of the Class III malocclusion.

In an anterior crossbite environment the attachment of the genioglossus muscle to the lingual surface of the mandibular symphysis is placed anteriorly to its normal relationship with respect to the maxillary incisors. This relationship carries the tongue tip anteriorly also. To achieve normal tongue-tip placement with respect to the maxillary incisors for the articulation of the phoneme /s/, the entire tongue must be retruded. This places the tongue tip in normal relationship to the maxillary incisors, but in a more posterior position when compared with the pterygomaxillary fissure and the lower incisors, and results in an alteration in the hyoid body position.

It was of interest to note that the Class III speakers depressed the mandible to a significantly greater degree than normal speakers during /s/ production. This mandibular maneuver

may represent an attempt to provide more space for lingual adjustment.

As seen in the cephalometric analysis of the observed skeletal relationships, the maxillae on the average tended to be smaller than the norm. The maxillae also demonstrated a posterior crossbite in five of the twelve cases in the experimental group. There would seem to be, then, a tendency for there to be insufficient physical space available within the confines of the maxilla for the tongue to easily form the long tube configuration against the maxilla, opening in the region of the incisors, that is required for the production of the phoneme /s/. In addition, the body of the tongue must be retracted to allow for the approximation of the tongue tip to the lingual area of the maxillary anterior teeth. The increased mandibular depression may be the means by which an attempt is made to acquire adequate space for the tongue to make these compensations.

This mandibular depression and rotation posteriorly may also be an attempt to provide for a more normal incisor-to-incisor relationship. Nevertheless, these adjustments in the lingual and dental posture were, for the most part, ineffective for achieving normal /s/ production. Thus the data cast serious doubt on the assumption that the speech problems associated with Class III malocclusion, specifically /s/ articulation, may be overcome by the learning of compensatory adjustments of the articulators without alteration of the anatomical environment.

The data of this study may also be viewed in relation to Bloomer's hypothesis that the tongue posture in Class III malocclusion "is habitually low and somewhat flaccid so that the constriction of the linguo-alveolar valve necessary for sibilants is not effectively produced." Visual inspection of the cephalometric films obtained in this study appeared to indicate that the Class III subjects tended to maintain a relatively low tongue posture. However, the findings of this investigation are not supportive of the presence of any flaccidity in the lingual musculature. Rather, the results obtained from the testing of lingual motor skills showed Class III subjects to be within normal limits for both verbal and nonverbal diadochokinetic tasks. Moreover, the findings of tongue retrusion at "rest," as well as during /s/ production, are suggestive of increased rather than decreased muscular tonus. Positional change of the hyoid body vertically during the /s/ production in the Class III subjects indicates contraction of the hyoglossus muscle, which also acts to depress and flatten the tongue. Contraction of this muscle during /s/ production would also inhibit the ability of the tongue to form an adequate central groove which is necessary for normal sibilant articulation. Perhaps depression of the mandible and/or the inhibitory action of the hyoglossus muscle upon the lingual blade making it more difficult for the tongue to reach the maxilla and the presence of the anatomical restrictions imposed by a small maxillary arch are the factors responsible for the acoustic distortion of sibilant articulation. The tongue, while in a retruded and flattened posture, is unable to establish an effective central groove which would significantly reduce the amount of turbulence the speaker is able to produce. Acoustically, the result in Class III speakers is what Luchsinger and Arnold describe as a "dull sibilant sound."[10] Studies designed to investigate the specific acoustical features of sibilant distortion that characterize all types of malocclusion would appear to have diagnostic and therapeutic importance.

Finally, it is of interest to compare the results of this study to the data of Subtelny, Mestre and Subtelny. Several

of the Class II speakers in their investigation were noted to engage in certain lingual-dental postures that allowed for normal /s/ articulation.

The lingual compensations noted by Subtelny et al. for Class II speakers were the opposite to those noted here for Class III speakers. In the Class II speakers with normal speech the tongue tip was retruded with respect to the maxillary incisors and was related normally to the mandibular incisors, and thus to the retruded mandible. In this sample the tongue tip was retracted with respect to the mandibular incisors and related relatively normally to the maxillary incisors.

In contrast to the Subtelny et al. sample of Class II, Division 1 speakers, although the subjects of this investigation demonstrated significant compensatory behavior for some lingual-dental parameters, only 1 of 12 achieved normal /s/ production.

The disparity in the findings is apparently due to the difference in the anatomic environment between the subjects. The Class II, Division 1 malocclusion does not restrict the operating space of the tongue. Therefore, it may be possible to establish a compensatory articulatory pattern which results in normal /s/ articulation. However, the relative maxillary deficiency found in Class III malocclusion may severely restrict the operating space of the tongue. The forward position of the anterior attachment of the tongue, with respect to the maxilla, may dictate that attempts at compensatory accommodations have less chance to be successful.

Also, the need to retract the tongue and to depress the mandible may place difficult muscular and spatial limitations upon the ability of the tongue to assume the configuration necessary to effectively articulate the /s/ phoneme.

It is important to note that the experimental sample was not made up of extreme Class III malocclusions, the type with which the clinical speech therapist, when presented with a need for correcting speech behavior, would not usually expect great results, but rather was the type of case in which extensive effort probably would be expended toward traditional articulation training.

The findings of this study suggest that speech therapy aimed at teaching normal articulation may not be effective in cases of Class III malocclusions until the oral environment has been corrected through orthodontic and/or surgical treatment.

Summary

In this investigation a group of individuals with Angle Class III malocclusions were studied radiographically to determine their tongue posture at rest and during phonation of /s/. Their speech and hearing was also evaluated. All of the subjects had normal hearing, while eleven of the twelve in the group showed some degree of sibilant distortion.

At rest, these Class III subjects demonstrated a tongue posture that was lower than normal and more retruded. During the phonation of /s/ these individuals also demonstrated retrusion of the tongue in an apparent attempt to achieve a normal relationship of the tongue tip to the maxillary anterior teeth, an increased amount of mandibular depression, and a greater than normal distance between the tongue tip and the mandibular anterior teeth.

Despite the compensatory movements exhibited by these individuals with Class III malocclusions, normal /s/ production was found in only one of the twelve subjects studied. This is in contrast to the successful compensations that result in normal /s/ production seen in a great number of individuals with a Class II, Division 1 malocclu-

sion, as demonstrated by Subtelny, Mestre and Subtelny.

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