Tongue Position and Hypernasality in Cleft Palate Speech

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For several years, various authors (*1*, *4*, *5*, *7*, *9*) have suggested that hypernasality usually associated with cleft palate speech is not only a function of velopharyngeal insufficiency but is related also to tongue positions assumed during articulation of the certain hypernasal sounds. (For the purpose of this report the word hypernasality is used in reference to resonance distortion of a consonant as opposed to nasal emission of air per se.) There has been little research to confirm the possibility that tongue position in addition to velar length and movement is related to hypernasality. Nohrstorm and Anderson (*8*) have found through x-ray study that the shape of the tongue of cleft palate children in swallowing is irregular and inconstant as compared with normal children. Buck (*2*) has indicated that there is no significant difference between cleft palate and normal speakers with regard to tongue positions assumed in the production of four English vowels.

The purpose of this study is to investigate whether tongue positioning is a contributing factor to hypernasality. Three questions were considered: what is the relationship between nasal quality and tongue positioning for production of the sounds /v, ð, z, ʒ/ by cleft palate children; do cleft palate and normal children assume different tongue positions in the production of the voiced fricative sounds; and are there differences in total oral cavity dimension between cleft palate and normal children during production of /v, ð, z, ʒ/.

Method

PROCEDURE. The experimental group was composed of thirteen males and seven females with repaired cleft palate. They represented a relatively wide range of socioeconomic areas from Detroit and its environs. Each subject had received from one to six years of speech therapy, the mean number of years being 3.25. Chronological age ranged from 82 months to 111 months with a mean of 97. Intelligence test scores, determined from school records, ranged from 68 to 140 (mean of 102). All experimental

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subjects had normal hearing, as defined by thresholds within 15 decibels re ASA, at 500, 1000, 2000, and 4000 Hz.

The control group, consisting of normal children, was matched with the experimental group on the bases of age, sex, intelligence, socioeconomic status and hearing acuity. Chronological ages of the control subjects were from 79 months to 115 months (mean of 97). The range of intelligence test scores was from 70 to 140 (mean of 97). In one instance, twins were used. All control children had normal speech, as determined by a sophisticated listener.

Standard lateral cephalometric techniques were employed to make radiographs of the head and neck during production of the voiced continuant fricative speech sounds /v, ð, z, ʒ/.

High fidelity tape-recordings of the sounds filmed were made simultaneously with the radiographs and dubbed onto a master tape. Recordings were judged on two separate occasions by three advanced graduate students in speech pathology for degree of hypernasality, using a four-point scale in which *zero* represented no hypernasality; *one* represented mild hypernasality; *two* represented moderate hypernasality; and, *three* represented severe hypernasality. Recordings of the control subjects and the experimental subjects were randomized. Listeners were instructed to disregard articulation placement for the consonants being judged and to base their ratings only upon hypernasality.

MEASUREMENTS. A total of 160 radiographs were taken of the forty subjects during production of the four sounds. Figure 1 specifies the 25 measurements which were made from each film. In order to make the first 22 measures, each film was placed on a wall-mounted Keleket x-ray viewing box. Vertical and horizontal lines were constructed as illustrated in Figure 2 and the distances measured in millimeters. All measurements were made to the nearest 0.25 mm on the enlarged roentgenographic image.

Measures 23, 24, and 25 were made by attaching a film to an x-ray view box which was placed flat on a table and then by tracing the periphery of a cavity with a Keuffel and Esser Compensating Polar Planimeter, Model No. 620005. For the purpose of this study, a planimeter was used to calculate area in square centimeters, to the nearest square millimeter. The mean value of three obtained measurements was used as the criterion value. As shown in Figure 3, the oral cavity was considered to be within the limits imposed by the anterior friction surface for production of the specific sound, the hard palate, the dorsum of the tongue, and a line through the midpoint of the velum or uvula to the tongue. The oropharynx was defined as bounded by the line from the midpoint of the velum or uvula to the tongue, the nearest point of velopharyngeal stricture, the posterior pharyngeal wall, and the horizontal line from the point at which the tongue curved into the oral cavity to the vertical line through the tubercle of the atlas bone. The laryngopharynx was defined as bounded by the glottis, the anterior and posterior pharyngeal walls, and the horizontal line con-

1. Upper central incisor teeth to tubercle of the atlas (incisal line) ($C–C_1$)
2. Midpoint of the atlas tubercle to Frankfort plane ($B–A_1$)
3. Quadrant of incisal line (not shown in Figure 1)
4. Midpoint of atlas tubercle to incisal line ($B–C_1$)
5. Distance between lips ($L–L_1$)
6. Distance between central incisor teeth (C–D)
7. Lower central incisor teeth horizontal to tongue tip (D–E)
8. Tongue tip anterior to upper central incisor teeth (C–T)
9. Tongue tip distance superior to line from lower central incisors to tongue tip (E–F)
10. Upper central incisors to high point of tongue ($C–H_1$)
11. Distance posterior to quadrant line in which high point of tongue occurs (not shown in Figure 1)
12. High point of tongue to hard palate (H–J)
13. High point of tongue to Frankfort plane (H–K)
14. Tongue to velum ($G–G_1$)
15. Oral aspect of velum to Frankfort plane (G–M)
16. Nasal aspect of velum to posterior pharyngeal wall (V–S)
17. Midpoint of nasal aspect of velum to Frankfort plane ($V–V_1$)
18. Infero-posterior tongue curvature to glottis (N–P)
19. Incisal line to glottis (N–Q)
20. Incisal line to point on nasal aspect of velum closest to postpharyngeal wall (V–R)
21. Infero-posterior curve of tongue to atlas line (Y–Z)
22. Oral cavity dimension
23. Oropharyngeal dimension
24. Dimension of laryngopharynx
25. Percentage of oral cavity anterior to high point of tongue
26. Nasality rating.

FIGURE 1. A description of the 26 measures used in this study.

structed from the curvature of the tongue to the vertical line through the anterior tubercle of the atlas bone.

Variable 25 was determined by dividing the value of $C–C_1$ by the value of $C–H_1$.

STATISTICAL PROCEDURES. There were eight sets of observations, one for each of the four sounds from each of the two groups. Each set contained measures for all twenty-six variables. The *t* test for matched groups was used to determine whether the differences between groups for each measure were significant. Pearson product-moment correlations were performed to determine whether there was a relationship between each measure and mean nasality ratings. Variable 26 was defined as the mean of the three judges' ratings. The consistency of each listener was determined by having him evaluate on two separate occasions the degree of hypernasality present in the utterances of each subject and then by testing the consistency of his responses with the Spearman rank-correlation procedure.

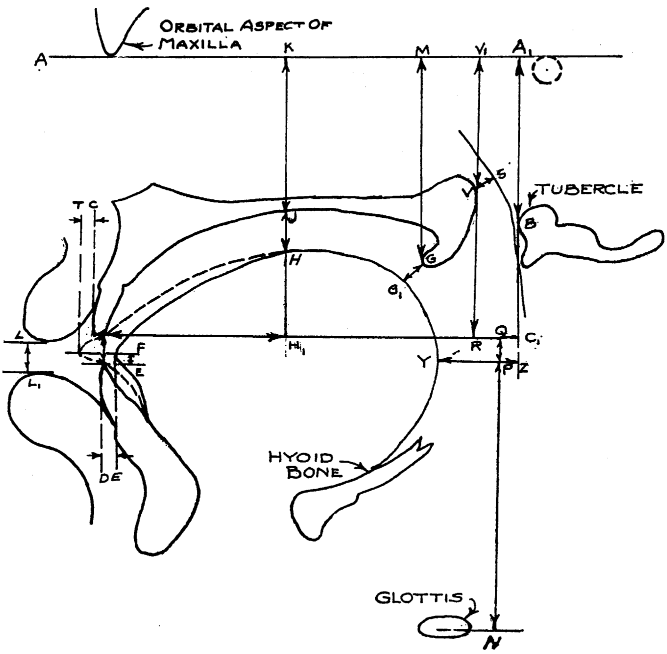


FIGURE 2. Line drawing showing origin and terminus points for measurements.

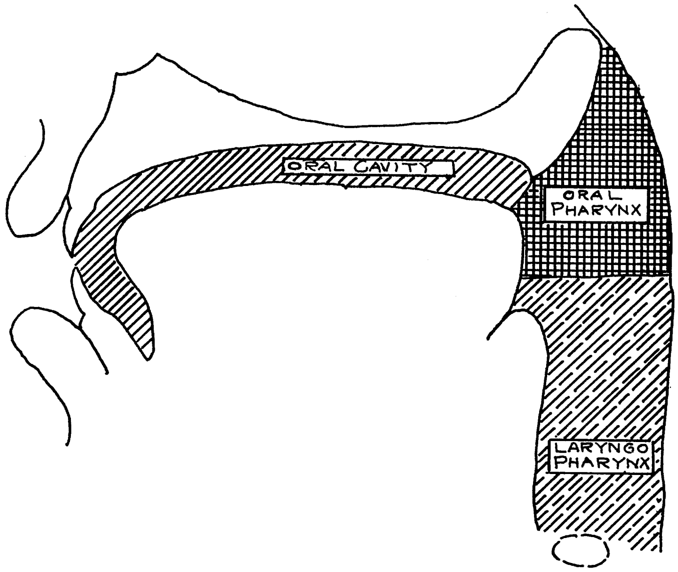


FIGURE 3. Schematic illustration of cavity boundaries.

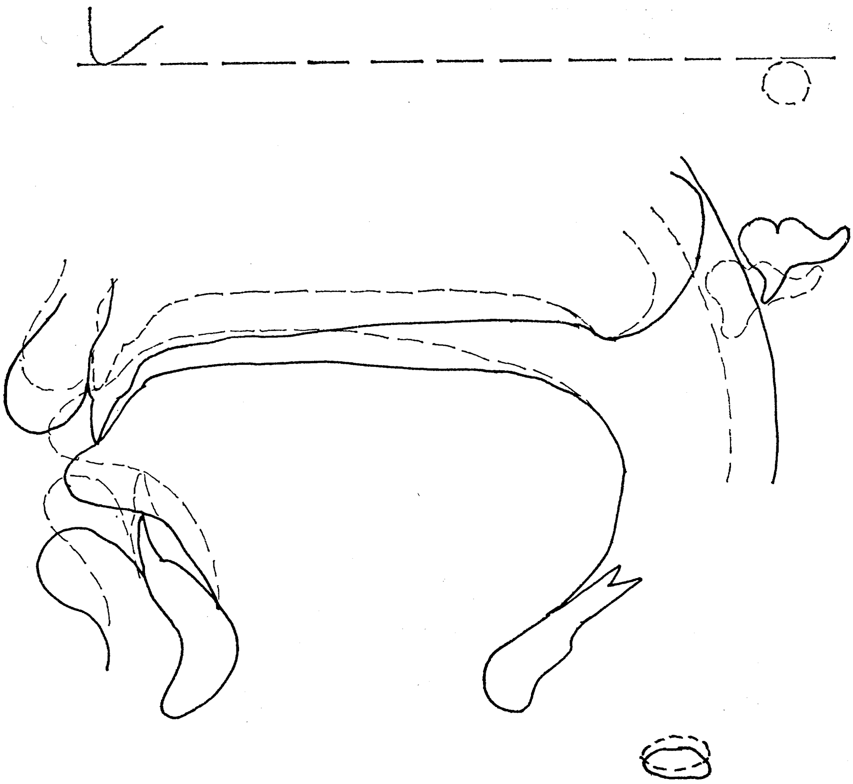
Results

The first hypothesis stated: There is a significant relationship between hypernasality and tongue positioning during production of voiced fricative continuant speech sounds by cleft palate children (see Table 1). This hypothesis is rejected for the /z/ sound since no tongue position variable (variables 7–14) was significantly correlated with nasality judgments for that sound. For /ð/, the hypothesis is supported with regard to variable 8, which is indicative of tongue retraction. For /v, ʒ/, resonance judgments correlated with variables 12 and 13, which are tongue height factors. This correlation supports the finding of Buck (*2*) that the vertical distance of the tongue from the palate tends to be greater for the cleft palate groups.

The second hypothesis stated: There is a significant difference between the tongue positions assumed in the articulation of voiced fricative continuant speech sounds by cleft palate and normal speakers (see Tables 2 to 5). This hypothesis is rejected for the /v/ sound since none of the differences in the tongue position variables (7–14) between the two groups was significant. It was accepted for the /ð/ and /z/ sounds, since there were significant differences between the two groups in tongue height and tongue retraction for these sounds. For the /ʒ/ sound, the only tongue measure which was significantly different between groups was with regard to the height of the tongue tip relative to the inferior central incisor teeth. In effect, therefore, the second hypothesis is also rejected for the /ʒ/ sound. Figures 4 and 5 illustrate composite mean measures for the first 21 variables for each group shown in Figure 1 for production of /ð, z/. In

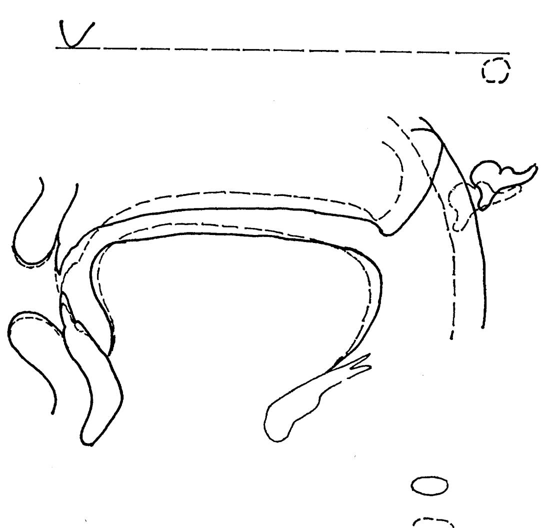
TABLE 1. Significant correlation coefficients between nasality ratings and each of 14 measurements, according to subject group (controls, C; experimental, E) and speech sound. No coefficients were significant between nasality ratings and measurements 1-5, 9, 14, 17, 21, 23, and 24.

measurement	/v/		/ð/		/z/		/ʒ/	
	C	E	C	E	C	E	C	E
6		−.50	−.42	−.61				
7							+.53	
8				−.41				
10							+.71	
11							+.45	
12								−.50
13		−.49					−.46	
15			−.44					−.97
16		+.49				+.56		+.47
18							−.46	
19			−.50					
20							−.51	
22					−.40			
25							+.70	



——————— = Control Group
-------------- = Experimental Group

FIGURE 4. Structural relationships for /ð/ sound.



——————— = Control Group
-------------- = Experimental Group

FIGURE 5. Structural relationships for /z/ sound.

TABLE 2. Differences between control and experimental groups for various measures on /v/; only differences which are significant at the 5% level are reported. All measurements are in mm, except for variable #22, which is in cm², and variable #26, which is an arithmetic computation.

variables	control		experimental			
	M	*SD*	*M*	*SD*	*D̄*	*t*
1. oral cavity length	74.22	4.41	70.08	6.20	4.14	2.12
2. atlas to Fr. plane	22.05	4.16	25.31	3.38	−3.26	2.67
3. quadrant	18.56	1.11	17.52	1.55	1.04	2.12
4. atlas to incisal line	17.00	6.91	12.45	5.84	4.55	2.23
16. velum to ph. wall	0.05	0.23	3.86	4.03	−3.81	4.21
17. velum to Fr. plane	15.65	3.40	19.79	7.02	−4.14	2.58
19. glottis to incisal line	39.16	7.11	43.02	7.78	−3.86	2.15
22. oral cavity area	12.75	4.71	10.21	2.39	2.54	2.40
26. nasality rating	.75	.55	1.85	.75	−1.10	5.77

general, these findings tend to refute the notions advanced by Van Riper (*10*), Buck and Harrington (*3*), and McDonald and Koepp-Baker (*6*) but support the findings of Buck (*2*) that cleft palate speakers tend to carry the tongue lower in the oral cavity than do normal speakers.

The third hypothesis stated: There is a significant difference in oral cavity size between cleft palate children and noncleft palate children for production of voiced fricative speech sounds (variables 15 to 25, Tables 2 to 5). This hypothesis is supported for all sounds. For each sound, the

TABLE 3. Differences between control and experimental groups for various measures on /ð/; only differences which are significant at the 5% level are reported. All measurements are in mm, except for variables #22 and #23, which are in cm², and variables #25 and #26, which are arithmetic computations.

variables	control		experimental			
	M	*SD*	*M*	*SD*	*D̄*	*t*
2. atlas to Fr. plane	21.39	3.82	25.18	3.54	−3.79	3.41
4. atlas to incisal line	17.49	7.00	11.61	5.97	5.88	3.05
7. L.C.I. to tongue tip	8.25	4.71	11.34	6.03	−3.09	2.22
10. U.C.I. to high point of tongue	5.08	2.58	9.65	8.94	−4.57	2.23
13. high point of tongue to Fr. plane	37.85	5.70	33.52	7.15	4.33	2.71
16. velum to ph. wall	0.26	1.14	4.77	4.49	−4.51	4.49
17. velum to Fr. plane	15.05	2.94	19.93	8.28	−4.88	2.57
19. glottis to incisal line	37.17	6.32	42.56	7.48	−5.39	2.96
20. velum to incisal line	21.78	5.62	15.76	7.02	6.02	2.97
22. oral cavity area	9.81	3.32	6.88	2.17	2.93	4.99
23. oropharynx area	3.36	1.34	4.78	2.37	−1.42	2.19
25. % of oral cavity anterior to high point of tongue	0.07	0.03	0.14	0.15	−0.07	2.16
26. nasality rating	0.85	0.75	2.05	0.89	−1.20	5.08

TABLE 4. Differences between control and experimental groups for various measures on /z/; only differences which are significant at the 5% level are reported. All measurements are in mm, except for variables #22 and #23, which are in cm^2, and variables #25 and #26, which are arithmetic computations.

variables	*control*		*experimental*			
	M	*SD*	*M*	*SD*	$\bar{D}$	*t*
2. atlas to Fr. plane	21.72	3.60	25.52	3.59	−3.80	3.49
4. atlas to incisal line	17.48	6.84	12.29	6.75	5.19	2.51
10. U.C.I. to high point of tongue	8.45	2.23	20.79	12.20	−12.34	4.27
13. high point of tongue to Fr. plane	33.91	5.49	30.20	8.39	3.71	2.16
15. velum to Fr. plane	32.71	4.66	28.75	6.31	3.96	2.49
16. velum to ph. wall	0.00	0.00	3.63	3.99	−3.63	4.08
17. velum to Fr. plane	15.90	3.32	19.99	7.21	−4.09	2.73
22. oral cavity area	8.64	2.16	7.06	1.82	1.58	3.03
23. oropharynx area	2.95	1.02	4.49	2.31	−1.54	2.95
25. % of oral cavity anterior to high point of tongue	0.12	0.03	0.30	0.17	−0.19	4.53
26. nasality rating	0.35	0.49	2.05	0.89	−1.70	9.49

TABLE 5. Differences between control and experimental groups for various measures on /ʒ/; only differences which are significant at the 5% level are reported. All measurements are in mm, except for variable #22, which is cm^2, and variable #26 which is an arithmetic computation.

variables	*control*		*experimental*			
	M	*SD*	*M*	*SD*	$\bar{D}$	*t*
2. atlas to Fr. plane	20.87	3.86	25.14	3.85	−4.27	4.11
4. atlas to incisal line	18.31	6.44	12.43	6.49	5.88	3.23
5. between lips	10.95	3.84	7.40	4.05	3.55	3.84
9. tongue tip above L.C.I.	4.28	3.00	0.51	5.32	3.77	3.18
16. velum to ph. wall	0.00	0.00	3.86	4.18	−3.86	4.13
17. velum to Fr. plane	15.42	3.01	21.33	8.37	−5.91	3.25
20. velum to incisal line	20.82	5.76	15.76	7.80	5.06	2.33
22. oral cavity area	7.46	1.73	6.03	2.17	1.43	2.51
26. nasality rating	0.40	0.60	2.05	1.00	−1.65	7.10

distance from the tubercle of the atlas to the Frankfort plane was significantly smaller for control subjects than for experimentals. However, the distance from the atlas tubercle to the incisal line was significantly smaller for experimental subjects than for controls. Both horizontal length of the oral cavity during /v/ and distance between lips during /ʒ/ were significantly greater for control subjects than for normals. Such findings indicate that the cleft group tends to modify the oral cavity by positioning the structure for articulation in such a way as to significantly restrict the cavity.

Discussion

Mention should be made of the finding reported here that the tubercle of the atlas is not the fixed anatomical structure that certain investigators have assumed it to be. Variations up to 2.5 millimeters were found in the present study, verified by measuring the distance of the cervical vertebrae from the vertical line through the anterior aspect of the tubercle for a subject from one sound to another. It was also possible to verify this finding by comparing distance from the tubercle to the external auditory meatus during production of the experimental sounds by a subject. In each instance, the measurements were identical, indicating that the shift was not a function of subject movement while fixed in the head holder. Further study of the films indicated that the shift was rotational in nature and that, since the tubercle is a curvilinear structure, when shifting occurred the apex of the tubercle was no longer parallel to the incisal line of the Frankfort plane and, instead, a point posterior to the apex was becoming the terminus of the line horizontal from the upper central incisor teeth. Such a finding would suggest that the atlas tubercle cannot be utilized as a fixed posterior point of reference for measurements of the functional nature of

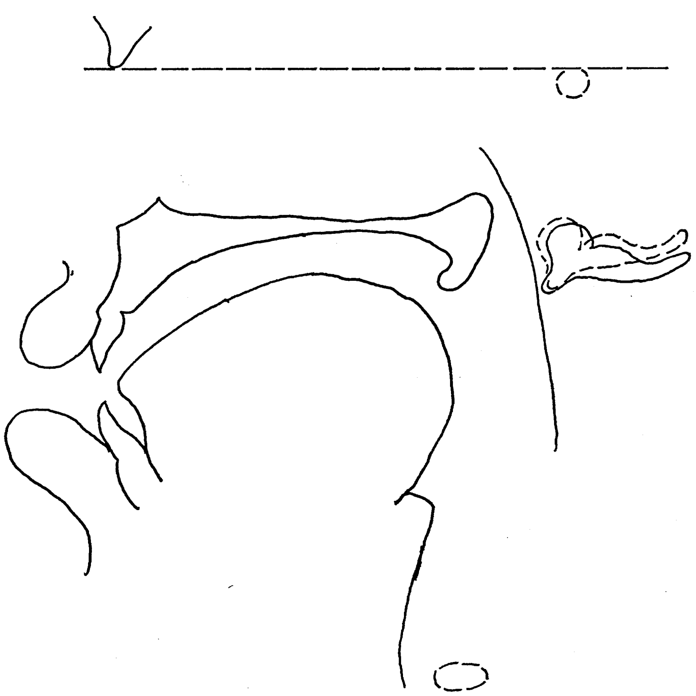


FIGURE 6. Lateral view illustrating nature of shift of anterior tubercle of atlas bone.

speech structures. Figure 6 illustrates that nature of the shift of the anterior tubercle.

One implication from this experiment concerns the advisability of studying the influence of age upon the relationship between articulatory position and associated hypernasality. Attempts to assign age differences as an influence in the findings of this experiment were inconclusive. It is possible, however, that sophistication, as a function of age, is operant in a reduction of the correlation between certain structural relationships and severity of hypernasality.

Summary

Twenty cleft palate children matched with twenty noncleft palate children were studied radiographically during production of /v, ð, z, ʒ/ and were tape-recorded during those radiographs to determine whether tongue position differences occur between groups and whether oral cavity dimension differences exist between groups. Significant relationships were found between certain tongue position factors and hypernasality for the /v, ð, ʒ/ sounds. Significant differences between groups were isolated for the /ð, z/ sounds. Finally, the oral cavity dimension for all sounds was found to be significantly greater for the control group than for the experimental group.

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