Cineradiographic Comparison of Normal to Noncleft Subjects with Velopharyngeal Inadequacy

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The individual who demonstrates velopharyngeal inadequacy without any evidence of congenital cleft presents a distorted voice quality and/or articulation defect as a result of this deficiency. For the past several years there has been a constant increase in referrals concerning this type of problem. In some instances, complete removal of tonsil and adenoid tissue was routinely done on these patients with the expectation nasality would be diminished. This procedure in actuality increased the nasal air flow, and so increased nasality.

The purpose of this research is to analyze the velopharyngeal deviations of patients with velopharyngeal inadequacies other than cleft palates and to compare the deviations to the velopharyngeal mechanisms of normal subjects. The authors believe the results of this pilot study will aid the various disciplines involved in the diagnosis and treatment of these individuals.

Kelly (*6*), Calnan (*3*), Randall, Bakes, and Kennedy (*9*), and Blackfield, Miller, Owsley, and Lawson (*1*), and others have reported etiological factors pertaining to velopharyngeal incompetency. All reports were based on visual, static roentgenographic, or cineradiographic studies.

Equipment

A specially designed cineradiographic unit was employed to record on film the function of the mandible, tongue, velum and surrounding tissue during phonation, blowing, and swallowing (Figure 1). The major components of the cineradiographic structure are: a rotating anode roentgen-tube with a .3 mm focal spot; a 9″ Keleket image intensifier tube with a light intensification factor of approximately 3600; an Auricon 16 mm motion

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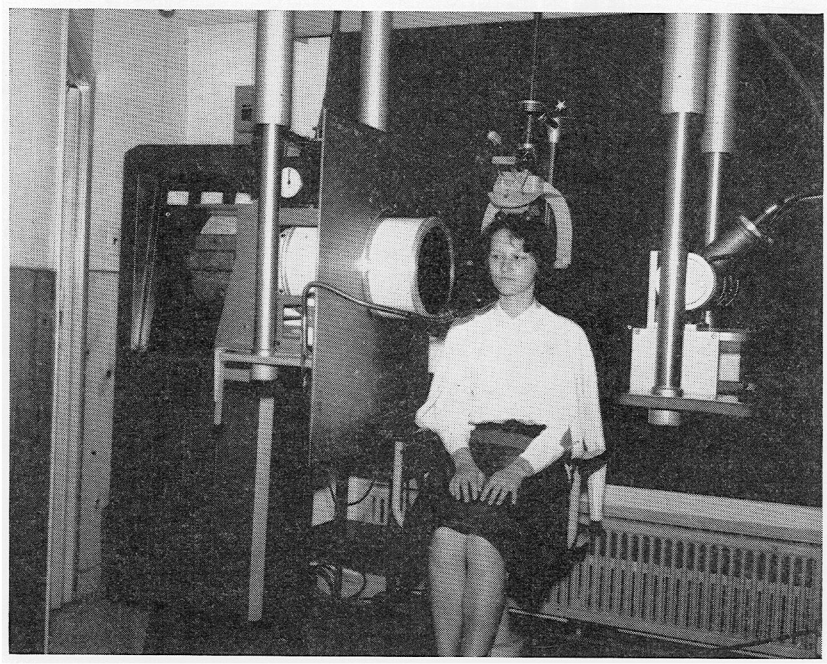

FIGURE 1. The cineradiographic unit records both roentgenographic motion pictures and the speech of the patient. This specially designed ceiling mounted apparatus supports the roentgen tube, cameras, radiation timer, and image intensifier. The intensifier reduces the radiation to the patient while increasing picture screen brilliance 3600 times. The head holder is attached to the chair.

picture camera with its optical system for recording sound-on-film data at 24 frames per second, and a timing device capable of accurately recording exposure time to 1/1000th of a second. A specially designed cephalostat consisting of ear rods and plastic forehead positioner calibrated to orient the patient to his initial position for subsequent studies was used for all subjects.

The distance between the roentgenographic tube and the intensifier tube is fixed. The tubes are adjusted so that the central rays of the roentgen tube will pass through the patient and strike the center of the receiving screen of the image intensifier. A full wave generator with an output smoothing device supplies the power for the rotating roentgen tube. The generator has a stepless control of both kilovolts and milliamperes. The sound-on-film recording apparatus is visually monitored for recording all data presented by the operator and/or patient. Settings of 65 to 75 kv and 1.75 ma were used throughout this study. A .27 mm copper and a .5 mm aluminum filter were utilized. Radiation dosage received by each subject, for 30 seconds duration, averaged .25r.

Subjects

Eleven subjects with velopharyngeal incompetency but without cleft palates were studied and compared with a control group of 10 normal

subjects matched according to sex and age. The subjects with velopharyngeal inadequacy ranged in age from 15 to 50 years. Three subjects were 17 years or less, five were between the ages of 20 and 30 years, and three were older than 30 years of age. There were two males and nine females. Two sets of consecutive brothers and sisters are included in the velopharyngeal inadequacy group. The normal control subjects varied in age from 15 to 45 years. Two of those subjects were 16 years or less, three were between the ages of 20 and 30 years, and three were between the ages of 30 and 40 years. Two were male and eight were female.

Surgical, medical, dental, speech, and audiometric information including cineradiographic and cephalometric studies, vital capacity readings, sound spectrograms, disc recordings, photographic slides, and intraoral movies of all patients with velopharyngeal inadequacies and normal subjects were available for analyses.

For subjects with velopharyngeal inadequacy, the soft palate appeared upon clinical examination to have sufficient length in all subjects. Three of the subjects had very little or no movement of the soft palate. Six patients were judged to have good to excellent mobility and two were judged to have fair mobility of the velum during phonation of /ɑ/. It was difficult to judge the size of the nasopharynx by visual examination. Two subjects had Class I bifid uvula. None of the group had evidence of submucous clefts. All cases had congenital velopharyngeal inadequacy. It was difficult clinically to establish the presence of neurological and/or muscular deficits in any of the cases. Six cases had their tonsils and adenoids removed prior to this study. Each subject had a nasal quality defect prior to that surgical procedure.

The 10 control or normal subjects were selected on the basis of not having any dental, medical, or speech deviation. None of the normal subjects was related to any other normal subject nor to any of the subjects in the abnormal group.

Procedure

All subjects were trained so that they would be familiar with the material and cineradiographic apparatus. Each subject used his habitual pitch level at his conversational volume level during the phonation of selected vowels, syllables, and connected speech. Each sequence was repeated in its entirety.

Voice quality judgments were independently judged by two speech pathologists employing a five-point scale where *one* was considered hypernasal, *three* normal, and *five* hyponasal. Another judgment, using a five-point intelligibility scale ranging from *one* (very poor) to *five* (normal), was independently made by the same speech pathologists. The correlation coefficient for quality was .93, and for intelligibility, .90.

High quality disc recordings cut on a Presto K-11 recorder and sonograms produced by the Kay Electric Sound Spectrographic Analyzer were also used in judging quality disturbances. The McKesson Scott Vital Capacity Apparatus was used to measure air loss through the nasal passageways for

the experimental group. The control group demonstrated no difference in vital capacity readings with the nose occluded and unoccluded.

Since it has been shown by Subtelny (*10*), Erickson (*5*), and others that the head in extension results in increasing pharyngeal depth, it is imperative that head position be controlled during the process of cineradiographic recording. In cases of incomparability of the cervical column to the base of the skull the projected image was not utilized for measurements.

Each subject was seated on a chair beneath a suspended cephalostat which is attached to the chair. Ear rods and four rubberized head positioners firmly held the head in such a manner that the midsagittal plane of the subject would be at a right angle to the central ray of the roentgen beam. The individual is further oriented so that the Frankfort Horizontal Plane is parallel to the floor. Exact positioning was checked with a Polaroid camera located over the eye piece of the viewing screen.

At the beginning of the cineradiographic study a plastic rod with embedded measured spheres was placed in the subjects' mouth to determine the enlargement factor.

A tracing cabinet was designed for projecting and tracing the cineradiographic film frame-by-frame as indicated (Figure 2). Each projected frame was traced on tracing paper applying the techniques of cephalometric roentgenography (*2*).

The tracing of the velopharyngeal area at rest was superimposed on the projected image during the production of /ɑ/ and the anatomic changes were traced (Figures 3 and 4).

Nine measurements were obtained from the films tracings. They are defined in the following ways: a) *Soft palate length:* The linear distance from the posterior nasal spine (PNS) to the tip of the uvula when the soft palate is at rest. b) *Thickness of the soft palate:* A line perpendicular to the line representing the length of the soft palate at the area of greatest velar thickness (Th) when the palate is at rest. c) *Depth of nasopharynx:* Linear distance along the palatal plane from the posterior nasal spine (PNS) to the posterior pharyngeal wall when the palate is at rest. d) *Height of elevation:* The measurement perpendicular to the palatal plane at the highest point of soft palate elevation during phonation of /ɑ/. e) *Height of closure:* The measurement between the highest point of closure of the soft palate perpendicular to the palatal plane, during phonation of /ɑ/. f) *Position of tubercle of atlas:* The measurement between the most prominent point of tubercle to the palatal plane along a perpendicular line. g) *Posterior pharyngeal wall forward movement:* The measurement between the most anterior point of tissue excursion and posterior pharyngeal wall along the line parallel to the palatal plane during phonation of /ɑ/. h) *Position of posterior pharyngeal wall forward excursion:* The measurement between the most prominent point of excursion to the palatal plane along a perpendicular line during the phonation of /ɑ/. i) *Gap:* The closest distance between the soft palate and the posterior pharyngeal wall during phonation of /ɑ/ along a line parallel

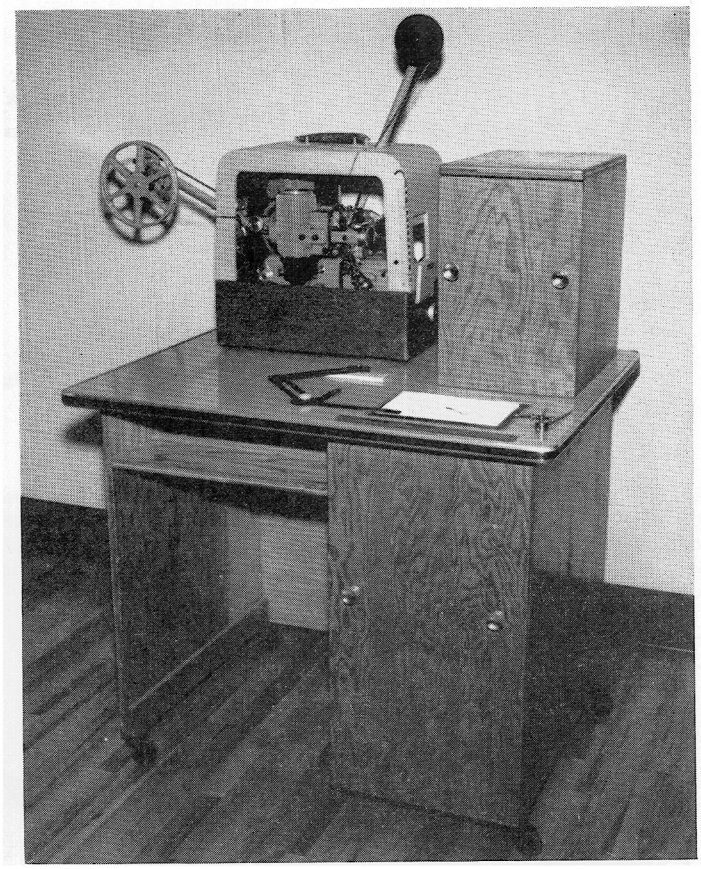

FIGURE 2. The tracing cabinet for frame-by-frame projection and tracing of the cineradiography film strips.

to the palatal plane. All measures were made to the nearest 0.5 mm on the enlarged tracing of the roentgenographic image.

Results

NORMAL GROUP. Table 1 presents data for the experimental and normal subjects. The soft palate length of normals varied from 31 mm to 39.5 mm with the mean of 34.6 mm and standard deviation of 3.153. The depth of nasopharynx in normal ranged from 23.5 mm to 31.8 mm with mean of 27.8 mm and standard deviation of 2.435. The correlation coefficient (r = .60) between the length and depth was significant at the 5% level.

The correlation coefficients between the following variables in normals were not significant: a) Depth of nasopharynx and height of elevation, r = .32; b) Length of soft palate and height of elevation, r = .24; c) Length of soft palate and height of closure, r = .003; d) Depth of nasopharynx and height of closure, r = .02; e) No correlation existed between length of soft

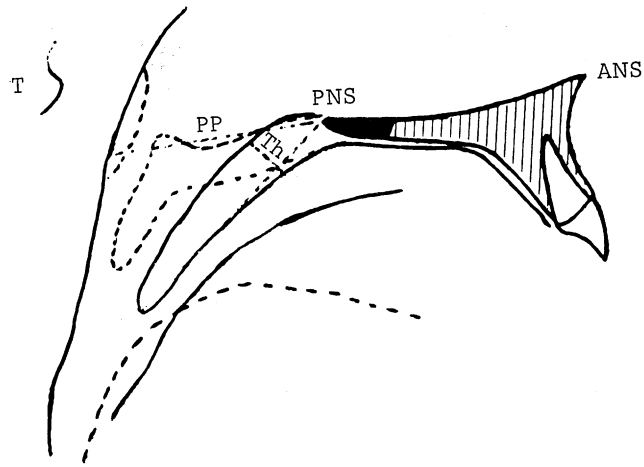

FIGURE 3. Superimposed tracing of a case with velopharyngeal incompentency. Solid Line: soft palate, tongue and posterior-pharyngeal wall at rest; broken line: soft palate, tongue and posterior-pharyngeal wall during phonation of sound /α/; T: tubercle of atlas; PP: palatal plane; PNS: posterior nasal spine; ANS: anterior nasal spine; and Th: thickness of soft palate.

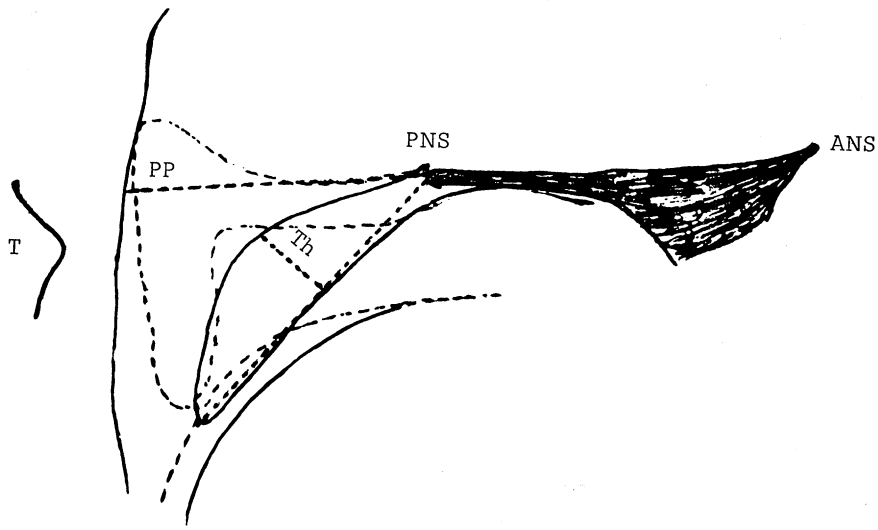

FIGURE 4. Superimposed tracing of a normal case. Solid Line: soft palate, tongue and post-pharyngeal wall at rest; broken line: soft palate, tongue and post-pharyngeal wall during phonation of sound /α/.

palate or depth of nasopharynx, and the height of elevation or height of closure.

These correlations reveal that the soft palate length and depth of nasopharynx do not appear to have any relationship to the height of elevation and height of closure. We could assume that the soft palate elevation and

TABLE 1. Obtained values, in mm, for seven measures for experimental (N = 11) and normal (N = 10) subjects. For height of elevation and height of closure, superscript A indicates above palatal plane and superscript B indicates below palatal plane.

Measures	*Range*	*Experimental Mean*	*SD*	*Range*	*Normal Mean*	*SD*
Soft Palate Length	27 to 40	31.2	4.654	31 to 39.5	34.6	3.153
Depth of Nasopharynx	25 to 36.5	29.4	3.674	23.5 to 31.8	27.8	2.435
Thickness of Soft Palate	5.3 to 7.9	6.5	0.215	6.5 to 13	9.2	1.521
Height of Elevation	6.7^{B} to 8.7^{A}	2.1	4.327	1.7^{B} to 7.6^{A}	2.6	2.961
Height of Closure	None	None	None	9.7^{B} to 7.6^{A}	−1.3	4.800
Gap	1.7 to 12.5	4.9	3.641	None	None	None
Posterior Pharyngeal Wall Forward Movement	0 to 7.7	2.0	2.391	0 to 2	None	None

velopharyngeal closure varies among normal individuals. The assumption, however, that to achieve velopharyngeal closure, the longer soft palate elevates lower than the shorter soft palate in normal subjects does not necessarily hold true.

In the normal subjects considerable variation existed between the height of elevation and the height of velopharyngeal closure. There was a significant difference between the mean height of elevation and the mean height of closure.

A wide variation was found in the position of the tubercle of the atlas in relation to the palatal plane in both normal and abnormal groups. The position of the tubercle in the normal group ranged from 13.3 mm below to 1.8 mm above the palatal plane. In the abnormal group the location of the tubercle of the atlas varied from 10.3 mm below to 11.3 mm above the palatal plane. In 80% of the normal and 60% of the abnormal the tubercle was located below the palatal plane.

By inspection, the variation in age of this sample group did not appear to have any effect on the length and depth.

VELOPHARYNGEAL INADEQUACY GROUP. The soft palate length in the velopharyngeal inadequacy group ranged between 27 mm to 40 mm with a mean of 31.2 mm and standard deviation of 4.654. The depth of the nasopharynx varied between 23.6 mm to 36.5 mm with a mean of 29.4 and standard deviation of 3.674. These relationships have the correlation coefficient of $r = .73$ which is significant at the 1% level. As in the normal population, the correlation coefficient between the soft palate length and depth of nasopharynx to the height of elevation for the velopharyngeal inadequacy group was not significant. The gap at the nearest distance between the soft

palate and the posterior pharyngeal wall during phonation ranged from 1.75 mm to 12.5 mm with the mean of 4.98 mm and standard deviation of 3.641. For 80 % of the subjects the gap was located below the palatal plane.

In 90 % of the subjects with velopharyngeal inadequacy the height of elevation did not represent the closest distance (gap) between the soft palate and the posterior pharyngeal wall during phonation. The correlation coefficient, $r = .80$, between quality judgment and intelligibility judgment was highly significant. There appeared to be no significant correlation between voice quality and size of gap ($r = .0055$). No significant correlation was found between size of gap and the percentage difference of vital capacity readings with nose unoccluded and occluded ($r = .25$). There was no significant correlation between the size of gap or difference in vital capacity readings and judgments of voice quality or intelligibility. There was no correlation between the differences of vital capacity with the nose occluded and unoccluded to nasal quality.

Based on this study, it appeared that the quality and intelligibility did not have a high correlation with the gap existing between the soft palate and posterior pharyngeal wall during phonation. We did not find any relationship between the degree of velopharyngeal inadequacy and the severity of the speech defect.

Between Group Comparison. The mean length of the soft palate in the normals was 3.7 mm greater than the mean length of soft palate in the velopharyngeal inadequacy group. The mean depth of nasopharynx was 1.6 mm shorter in normal group than the mean of the abnormal population.

Based on these data, it appears that the depth of the nasopharynx in the abnormal is closer to normal measurement than the length of the soft palate in the abnormal.

The difference between the mean length of the soft palate and the mean depth of nasopharynx in normals was 6.8 mm. In the abnormal group the difference of these means was 1.8 mm. We can state that the soft palate length in the velopharyngeal inadequacy group was shorter than normals and the depth of nasopharynx in abnormal group was greater than in the normals.

In all normal subjects the length of soft palate was greater than the depth of nasopharynx. However, in the velopharyngeal inadequacy group there were three cases in which the length of the soft palate and depth of nasopharynx had equal measurements. Two cases in this group had depth of nasopharynx greater than length of soft palate.

The significance of the difference between the means for soft palate length in the normal and abnormal groups was tested by a t test and was significant. The t test was used also to evaluate the significance of the difference between means of the depth of the nasopharynx for normal and abnormal groups and was found not to be significant.

The height of elevation did not vary considerably between normal

subjects and the velopharyngeal inadequacy group. In 70 % of the normal and abnormal cases the soft palate elevated above the palatal plane.

In 80 % of the normal subjects, the height of velopharyngeal closure took place below the palatal plane. Velopharyngeal closure was absent in all subjects with a velopharyngeal inadequacy. Three of the subjects with velopharyngeal inadequacy showed complete closure during blowing whereas all normal subjects obtained closure during phonation and blowing.

A significant difference was found in the thickness of the soft palate in normals and abnormals. One may consider that the abnormal growth might have been caused by the lack of proper function of the soft palate and/or neuro-muscular deficit.

One of the normal subjects showed 2 mm of forward movement of the posterior pharyngeal wall (Figure 5). None of the others appeared to have any movement of the posterior pharyngeal wall during phonation or blowing. Seven of the patients with velopharyngeal inadequacy had forward movement of the posterior pharyngeal wall which varied in extent from .7 mm to 7.7 mm with a mean of 2.7 mm. Four did not have any movement (Figure 6). In five subjects with velopharyngeal inadequacy the position of the most prominent point of posterior pharyngeal wall excursion coincided with the nearest distance between the soft palate and this forward projection during phonation.

Remarks

Surgical treatment to the palate should be based on the type of deficiency present. When the deficiency is caused by an increased depth of the nasopharynx the recommended treatment should be confined to the nasopharynx rather than to the velum. When palatal length or mobility of the velum is effected, then treatment should be confined to the lengthening of the velum combined with or without a pharyngeal flap.

In cases where velopharyngeal closure during phonation is inconsistent, where a point rather than an area of contact exists, intensive speech therapy should be initiated before considering any other type of treatment.

With an increase in intelligibility there is a proportional decrease in nasal voice quality. In those subjects whose quality and intelligibility were judged as poor and the gap between the soft palate and posterior pharyngeal wall was small, it would appear that factors other than gap distance affects voice quality. Other factors affecting quality may be amount of mouth opening, rate of speech, pitch level, and faulty articulation due to poor habits of tongue positioning.

Prosthetic treatment should be considered when both depth of nasopharynx and mobility of the velum are markedly affected and when stimulation of posterior and lateral pharyngeal wall activities prior to surgical procedures is indicated (*8*).

To obtain optimum speech for the patient the cause of velopharyngeal

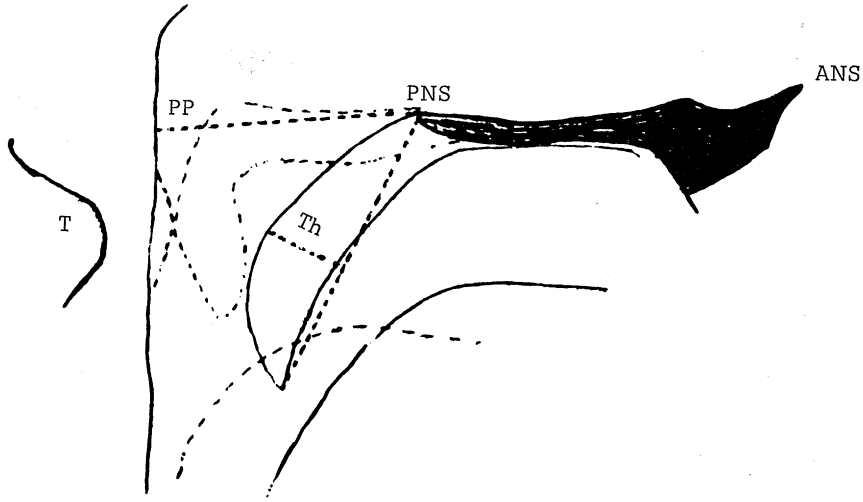

FIGURE 5. Tracing of a normal case with 2 mm forward excursion of posterior pharyngeal wall.

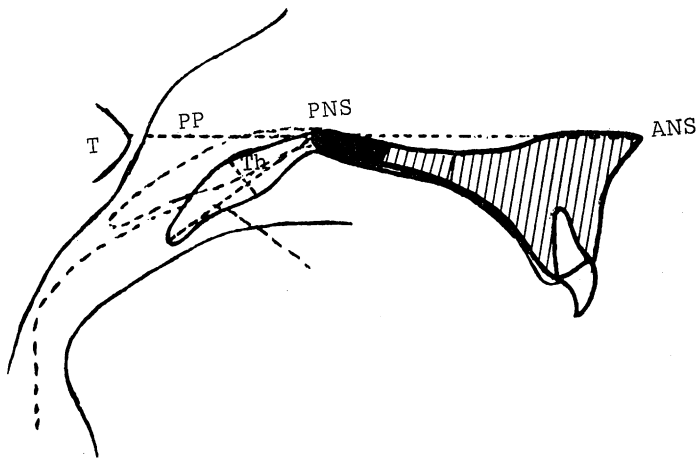

FIGURE 6. Tracing of a representative of 4 cases with velopharyngeal incompentency without forward excursion of the posterior pharyngeal wall.

deficiency must be adequately diagnosed. Cineradiographic studies of velopharyngeal function are an excellent aid to overall diagnostic procedures (*4*, *7*, *11*).

Summary

Cineradiographic studies of the normal subjects were compared with studies of noncleft subjects who demonstrated velopharyngeal inadequacy. The following conclusions were made: a) There was a significant difference between soft palate length in normals and the velopharyngeal inadequacy

group. b) There was not a significant difference between depth of nasopharynx in normal and the velopharyngeal inadequacy group. c) The difference of the means of the soft palate length and depth of nasopharynx between the normals and velopharyngeal inadequacy group was significant. d) The thickness of the soft palate was greater in the normal than the abnormal group. e) In 70% of the normal and velopharyngeal inadequacy groups the height of soft palate elevation was above the palatal plane. f) In 80% of the normal group the height of velopharyngeal closure took place below the palatal plane. None of the subjects in the velopharyngeal inadequacy group obtained velopharyngeal closure. g) There was no significant correlation between amount of gap and voice quality. h) There was no significant correlation between amount of gap and intelligibility of speech. i) There was a difference between vital capacity readings for the velopharyngeal inadequacy group with nose occluded and unoccluded. j) The correlation coefficient between quality judgment and intelligibility judgment was highly significant.

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