

Roentgenographic Cephalometric Study of Palatopharyngeal Closure of Normal Adults during Vowel Phonation

DAVID BENSON, D.D.S., M.S.
Los Angeles, California 90024

Introduction

An understanding of normal palatopharyngeal physiology during speech is essential in the diagnosis and treatment of palatopharyngeal dysfunction. Normal palatopharyngeal function in speech has been studied utilizing both cineradiography (1-9) and cephalometric roentgenography (10-16).

The main advantage of cineradiography is it provides a continuous appraisal of the palatopharyngeal mechanism during connected speech. However, cineradiographic projections lack detail and the necessary equipment is expensive.

Cephalometric roentgenography gives a detailed image of palatopharyngeal activity but is a static representation of function. Cephalometric films of palatopharyngeal relationships during sustained sound production do, however, have predictive value in defining the potential for closure during continuous speech (17). Cephalometric roentgenography is relatively economical and more accessible than cineradiography.

In clinical practice cephalometric roentgenography is the procedure of choice to quantify the degree of level of velar elevation and the vertical dimension over which palatopharyngeal contact is established (17).

Although cephalometric roentgenography has been used to research normal palatopharyngeal physiology during speech, the parameters of normal palatopharyngeal relationships are still in question, particularly as they relate to diagnosis and treatment of dysfunction.

The purpose of this study was to further investigate normal palatopharyngeal closure during sustained phonation of the vowels /a/, /i/, /u/ on adult subjects, utilizing roentgenographic cephalometrics. Palatal length, pharyngeal depth, height of closure, posterior pharyngeal wall movement, and residual lumen opening were analyzed and discussed relative to previous roentgenographic studies of normal palatopharyngeal closure. The results were also discussed relative to the positioning of speech aid prothesis.

Dr. David Benson is Assistant Professor, Division of Removable Prosthodontics, School of Dentistry, University of California at Los Angeles, Los Angeles, California.

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Procedure

SAMPLE. 15 adult males and 15 adult females within a range of 20 years to 40 years and having a mean age of 27.2 years. To fulfill the requirement of "normal" all subjects met the following qualifications:

- (1) Had never had speech therapy
- (2) Had never worn any type of speech-aid appliance
- (3) Speech is considered "socially acceptable"

For the purpose of this study "socially acceptable speech" is that in which no type of deviation can be detected by an untrained listener.

The subjects were graduate students, dental students, dental hygiene students, dental assistants, and graduate dentists.

CEPHALOSTAT. A Wehmer cephalostat with rotating anode source of radiation was used to take the lateral cephalograms. The anode film distance was five feet and the distance from porion plane to film was 7.25 inches. Exposure time depended on the sex, physical stature, and age of the patient.

CEPHALOMETRIC PROCEDURE. Lateral cephalograms were taken on the subjects at rest, and during the phonation of /a/, /i/, and /u/. Thirty subjects were studied during the sustained phonation of /a/ and /i/, and 23 of the subjects were studied during the phonation of /u/. Before the cephalograms were taken each subject was trained to sustain a conversational pitch and intensity during the phonation of each vowel studied. The individuals were instructed to maintain the phonation of each vowel during the entire radiographic exposure time.

TRACING PROCEDURE. The standard cephalometric anatomical landmarks (18) and associated structures were located and traced on .003 inch acetate for the cephalograms of each subject at the rest position (Figure 1).

On the tracings at rest position the following linear measurements were made to the nearest half millimeter.

- (1) *Pharyngeal depth*—The distance from the posterior nasal spine (PNS) to the posterior pharyngeal wall (P_h) measured along the palatal plane (PP).
- (2) *Resting palatal length*—The distance from the posterior nasal spine (PNS) to the most posterior-inferior point on the resting velum (V_r).
- (3) *Position of the atlas tubercle relative to the palatal plane*—The distance measured perpendicular from the palatal plane (PP) to the most anterior point on the atlas tubercle (A_t).

Duplicate tracings for each subject at rest position were superimposed on the cephalograms of /a/, /i/, and /u/ using the landmarks of sella, nasion, anterior nasal spine, and the pterygomaxillary fissure. The position of the soft palate (V_1), the tubercle of the atlas (A_t) and the posterior pharyngeal wall (P_{h_1}) were traced on the cephalograms taken during the phonation of /a/, /i/, and /u/ (Figure 2).

On the tracings of the lateral cephalograms during the phonation of /a/,

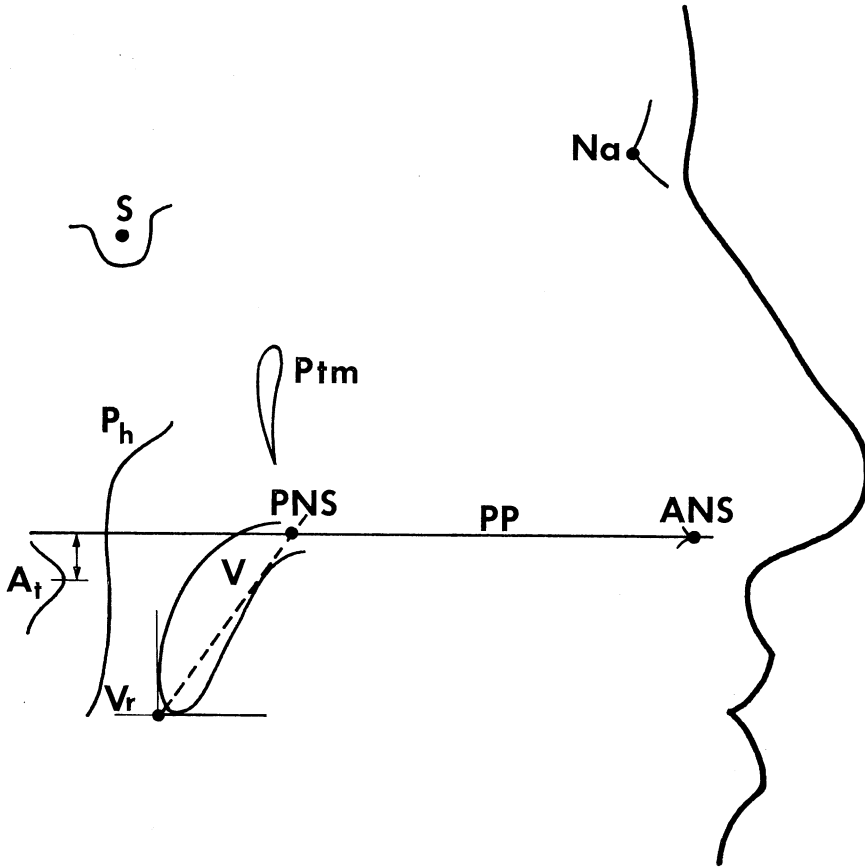


FIGURE 1. (S)—Sella, (Na)—Nasion, (ANS)—Anterior nasal spine, (Ptm)—Pterygomaxillary fissure, (V)—Soft palate—contour of the resting soft palate, (V_r)—Most posterior-inferior point on resting soft palate, (P_h)—Posterior pharyngeal wall—contour of the soft tissue of the posterior pharyngeal wall, (A_t)—Atlas tubercle—contour of the anterior tubercle of the first cervical vertebrae or atlas, (PP)—Palatal plane—located by connecting ANS and PNS.

/i/, and /u/, the following measurements were made to the nearest 0.5 mm:

- (1) *Residual lumen*—Evaluated on either an “open” or “closed” basis.
- (2) *Height of palatal closure or point of greatest mid-sagittal palatopharyngeal constriction*—
 - (a) Relative to the palatal plane—The perpendicular distance from the palatal plane (PP) to the midpoint of the contact of the functioning palate with the posterior pharyngeal wall (or to the midpoint of the greatest constriction between the functioning palate and the posterior pharyngeal wall in the mid-sagittal plane).
 - (b) Relative to the tubercle of the atlas the perpendicular distance from the most anterior point on the tubercle (A_t) to the midpoint

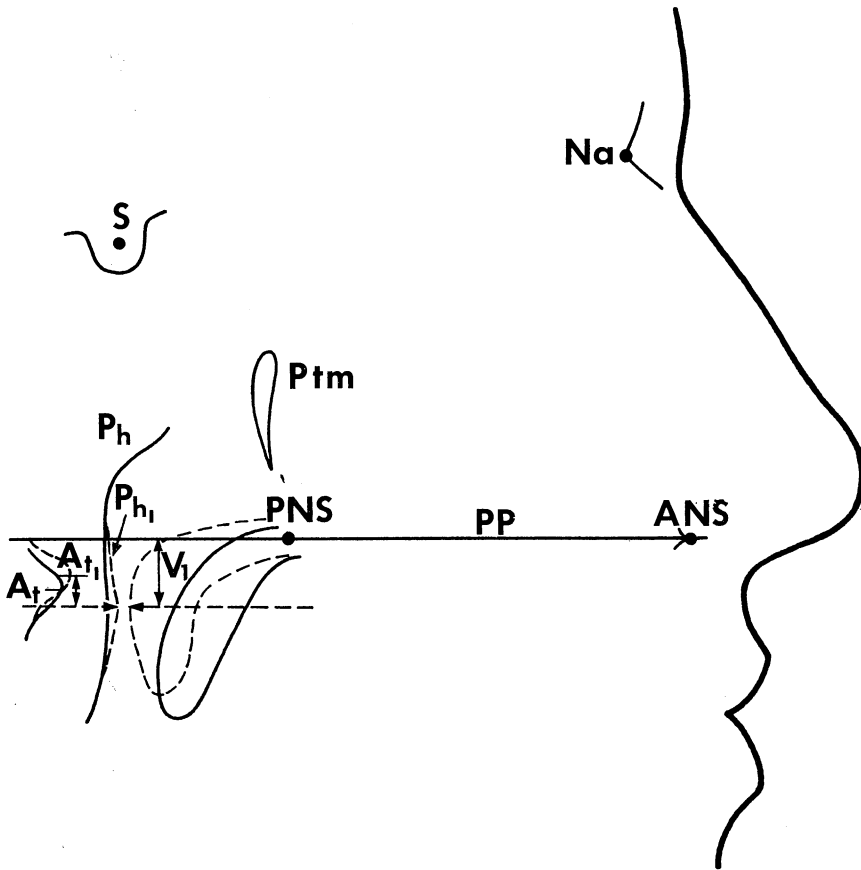


FIGURE 2. (V_1)—Contour of the functioning soft palate, (A_{t_1})—Contour of the atlas tubercle during phonation, (P_{h_1})—Contour of the soft tissue of the posterior pharyngeal wall during phonation.

of contact of the functioning palate with the posterior pharyngeal wall (or to the midpoint of greatest constriction between the functioning palate and the posterior pharyngeal wall in the mid-sagittal plane).

- (3) *Posterior pharyngeal wall movement*—The greatest distance from the posterior pharyngeal wall at rest (P_h) to the posterior pharyngeal wall during phonation (P_{h_1}).

Results and Discussion

RESTING PALATAL LENGTH AND PHARYNGEAL DEPTH. The mean resting palatal length and the mean pharyngeal depth were found to be 37.3 mm and 33.2 mm respectively, a mean difference of 4.1 mm (Table 1). These determinations were within the range reported by other investigators (2), (3), (5), (9).

TABLE 1. Resting palatal length—pharyngeal depth

	<i>mean (mm)</i>	<i>standard deviation</i>	<i>max (mm)</i>	<i>min (mm)</i>	<i>range (mm)</i>
palatal length.....	37.3	4.24	47.5	29.5	18.0
pharyngeal depth.....	33.2	4.00	46.0	26.0	20.0

Four of the 30 individuals in this study with normal palatopharyngeal function during speech showed a resting palatal length that was less than the pharyngeal depth. This suggests that the potential of the velum to produce palatopharyngeal closure can not always be predicted from measurements of the resting soft palate length. Bzoch (2) has shown there is a significant increase in the length of the functioning velum over that of the resting velum. Pruzansky (13) has demonstrated similar results and has termed the increase in the functioning palatal length as the "stretch factor".

The linear correlation coefficient between the length of the resting palatal length and the pharyngeal depth was 0.43, suggesting no strong relationship between these factors.

RESIDUAL LUMEN. During the sustained phonation of /a/, the soft palate did not contact the posterior pharyngeal wall in 63 percent of the individuals. Williams (14), in a serial cephalometric study of palatopharyngeal closure on normal males reported the palatopharyngeal lumen was open during the phonation of /a/ in 29 out of 30 cases (96.7 percent). In a similar investigation using cinefluorography, Moll (6) found the lumen open in 37 % of the cases during the phonation of /a/. The results of this study and the investigations by Williams and Moll do no support the hypothesis that the palatopharyngeal valve is closed for all vowels.

In this study the palatopharyngeal lumen was open in 23 percent of the subjects during the phonation of /i/ and in 9 percent during the phonation of /u/. Williams and Moll reported similar results.

HEIGHT OF PALATAL CLOSURE. The term "height of closure," is the height of contact between the soft palate and the posterior pharyngeal wall relative to a plane of reference. However, there is not always actual physical contact of the soft palate with the posterior pharyngeal wall during phonation.

By arranging data regarding the point of actual palatal contact with the pharyngeal wall together with data concerning the area of greatest palatopharyngeal constriction when the lumen was open, the mean height of palatal closure was determined to be 4.38 ± 2.51 mm. below the palatal plane during the phonation of /a/ (Table 2). The mean height of palatal closure was also calculated: (1) palatopharyngeal lumen open (19 of 30 subjects), (2) palatopharyngeal lumen closed (11 of 30 subjects). The mean height of palatal closure during the phonation of /a/ was: (1) 1.9 mm below the palatal plane with the lumen closed, (2) 6.05 mm. below the palatal plane with the lumen open.

TABLE 2. Height of palatal closure.*

<i>vowel</i>	<i>mean height of† palatal closure (PP)</i>	<i>mean height of palatal closure (atlas)</i>	<i>mean position of atlas to PP</i>
/a/	-4.38 ± 2.51	+2.36	-6.56
/i/	-0.29 ± 1.71	+6.25	-6.56
/u/	+0.80 ± 1.47	+6.40	-6.56

* - indicates below; + indicates above.

† at 95 percent confidence level.

To group this type of data without specifically defining "height of closure" is misleading. This information should be reported as (1) "the height of palatal closure" (to indicate actual palatal contact) and (2) "the height of the area of greatest palatopharyngeal constriction." The height of closure was 0.29 mm below the palatal plane during the phonation of /u/ and 0.8 mm above the palatal plane during the phonation of /u/.

A paired t-test shows that the height of closure for /i/ and /u/ are statistically different from the height of closure for /a/ at the 95 percent level of confidence. The height of palatopharyngeal closure depends on the phoneme that is being studied and it is impossible to make a valid statement that all closure occurs at a specific level. Mazaheri (5) studied palatopharyngeal closure during the phonation of /a/ and found closure took place below the palatal plane in 80 percent of the normal group.

Aram and Subtelny (10) have found that the midpoint of closure in reference to the palatal plane was constantly above the palatal plane during phonation of /u/.

The height of palatopharyngeal closure has significant clinical implications on the placement of the pharyngeal section of a speech aid appliance. The location of the pharyngeal section of the speech appliance can be classified according to the following philosophies: (1) Baden (19) proposes placement of the pharyngeal section at the level of the atlas tubercle. (2) Gonzales (20) states the pharyngeal section off the "palatal lift" speech aid appliance should be at the level of the palatal plane, (3) Aram and Subtelny (10) locate the pharyngeal section of the speech appliance above the palatal plane, and (4) Lange (21) develops the pharyngeal section of the "palatal lift" appliance below the palatal plane in the area of greatest palatopharyngeal constriction for the vowel /a/.

There is no one location of the pharyngeal section of a speech appliance that will meet the specific requirements for all cases. From the findings of this study and similar reports, the mean palatopharyngeal closure during phonation of /a/, /i/, and /u/ will occur in a range from 4.38 mm below the palatal plane to 0.8 mm above the palatal plane. The position of the atlas tubercle is highly variable and is not a dependable landmark to be used relative to palatopharyngeal closure. As a general guide, it would be more logical to place the pharyngeal section of a speech aid appliance

TABLE 3. Posterior pharyngeal wall movement.

<i>vowel</i>	<i>mean movement_i(mm)</i>
/a/	1.20
/i/	1.17
/u/	1.09

within the range of normal palatopharyngeal closure. The exact optimum location should be determined by developing the pharyngeal section for each patient with the aid of a speech pathologist.

POSTERIOR PHARYNGEAL WALL MOVEMENT. The results of this study are consistant with previous reports (1), (3), (9), (10) show insignificant posterior pharyngeal wall movement during the phonation of /a/, and /i/, and /u/ (Table 3). A distinct Passavant's Pad was observed on 4 of the 30 individuals studied. On the individuals where Passavant's Pad was recorded, it was too low to be effective in palatopharyngeal closure. Calnan (22) has reported similar observations.

Summary

(1) In 87 percent of normal individuals the resting palatal length is greater than the pharyngeal depth.

(2) The residual palatopharyngeal lumen is open for: (1) 63 percent of normal individuals phonating /a/, (2) 23 percent of normal individuals phonating /i/, and (3) 9 percent of normal individuals phonating /u/.

(3) The mean height of palatal closure on normal individuals was: (1) 4.38 mm below the palatal plane during the phonation of /a/, (2) 0.29 mm below the palatal plane during the phonation of /i/, and (3) 0.80 mm above the palatal plane during the phonation of /u/.

(4) The height of palatal closure was statistically different when comparing the vowel /a/ to /i/ and the vowel /a/ to /u/.

(5) The mean height of palatal closure on normal individuals during the phonation of /a/, and /i/, and /u/ is above the atlas tubercle.

(6) The amount of posterior pharyngeal wall movement on normal individuals during the phonation of /a/, /i/, and /u/ was minimal.

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