A Cephalometric Investigation of Velar Stretch

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In an evaluation of the velopharyngeal mechanism two questions must be answered. First, it must be determined if the mechanism is functioning properly. Second, it must be determined if the mechanism is structurally adequate.

There are many methods used to help determine structural adequacy, with one of the traditional methods utilizing some type of lateral radiography. From these, measures are made to help determine anteroposterior tissue adequacy. The pharyngeal depth is determined, velar length is determined, and these two measures are compared to determine if the structure is sufficient to enable the patient to achieve closure (*9*). This procedure assumes that the measures of the mechanism taken at physiological rest would be the same if the measures were taken during function. Specifically, the assumption is made that 1) the pharyngeal depth is constant from rest to function, and 2) velar length is constant from rest to function.

The first of these assumptions, pharyngeal depth, has been studied extensively (*1–4, 6*) and although there is not total agreement, the consensus is that pharyngeal depth does remain fairly constant for a normal population. Variations in pharyngeal depth have been reported but these are not extremely common and are usually considered to be a compensation developed by a person with an abnormal mechanism.

The second assumption of velar length has not been so thoroughly investigated. In 1959, Graber, Bzoch and Aoba (*5*), studying normal subjects, reported "that there is a significant increase in length of the palate from rest to the functional position." They stated that "these measurement changes in length are not interpreted as meaning actual incremental increase but rather as evidence of the incorporation of tissue elements from the lateral pharyngeal walls."

Bzoch (*1*), utilizing five normal adult subjects producing syllables, reported an increase in velar length from rest to function of 49% with the mean length at rest being 33.00 mm. and the mean length in function being 49.28 mm.

Westlake and Rutherford (*10*) referred to the lengthening of the velum by stating that "the posterior pull of the levators ... probably accounts

for at least part of the stretching that increases the length of the functional portion of the velum in closure."

Pruzansky and Mason (*8*), studying 110 patients with congenital palatopharyngeal incompetence reported that "in some individuals the soft palate (velum) increased in its intrinsic length during velopharyngeal valving." They postulate that "the stretch factor is an active process analogous to the lengthening contraction in the co-contraction of an antagonistic muscle. This phenomenon is dependent upon the load imposed, the available muscle mass, the range and speed of movement, and the activity of other muscles involved in the synergy."

The implications of this phenomenon are many. A thorough understanding of velar stretch would permit an estimate of stretch potential for a specific individual. This estimate of stretch potential would enable clinicians to more accurately determine the need for morphological changes or to predict the success of speech therapy. In order to begin to gain this understanding two experimental questions were asked: 1) When velar stretch occurs, is the amount of stretch equal throughout the velum or are there differences between the anterior portion and the posterior portion of the velum? And, 2) when velar stretch occurs, is there a correlation between the amount of stretch and other cephalometric measures commonly employed during clinical evaluations of the velopharyngeal structure?

Procedure

SUBJECTS. Twenty subjects, 10 male and 10 female, ranging in age from 18 to 30 years were selected for this study. Criteria for subject acceptance was that they display normal articulation and resonance balance and have no history of clefts or palatal insufficiencies.

EQUIPMENT AND CEPHALOMETRIC PROCEDURE. Lateral cephalometric x-rays were taken with a General Electric Dental X-ray Unit (G.E.-100). The headholder was a Wehmer Cephalostat. Each subject was seated in a dental chair and the posterior nasal spine and the velar eminence were marked on the oral surface of the palate with an indelible ink pencil. Spherical lead markers were then attached to the posterior nasal spine and the velar eminence by means of a commercial dental adhesive. Each marker had an average weight of .08 grams and each spot of adhesive had an average weight of .06 grams. The subject was then placed in the cephalostat.

Three lateral cephalometric x-rays were taken. The first exposure was made at physiological rest. The second exposure was taken during the production of a sustained /s/. The third exposure was also taken at physiological rest to insure that the markers had not moved.

MEASUREMENT PROCEDCRES. Tracings of the first two x-rays for each subject were made on acetate transparencies and all measures were taken from these tracings. Figure 1 shows the velum during physiological rest

FIGURE 1. Sample of X-ray taken at physiological rest with markers in place.

and Figure 2 shows the velum during sustained production of /s/ with the markers in proper position. Point A (Figure 3) represents the posterior border of the lead marker placed at the posterior nasal spine and point B represents the posterior border of the lead marker placed at the velar eminence.

The tracing procedure and the measurements used are shown in Figures 3, 4, and 5. These measurements are defined as follows:

1. Velar length (rest–AC) (function–A′C′). Midline distance was measured from the posterior surface of the posterior nasal spine marker to the tip of the uvula.
2. Length of the anterior portion of the velum (rest–AB) (function–A′B′). Anterior portion of the velum was measured on a midline between the posterior surface of the posterior nasal spine marker and the posterior surface of the velar eminence marker.
3. Length of the posterior portion of the velum (rest–BC) (function–B′C′). Posterior portion of the velum was measured on a mid-

FIGURE 2. Sample of X-ray taken during function with markers in place.

line between the posterior surface of the velar eminence marker and the tip of the uvula.

4. Pharyngeal depth (HI). Depth of the nasopharynx was measured along the palatal plane from the posterior surface of the posterior nasal spine marker to the posterior pharyngeal wall during physiological rest.
5. Velar thickness. The thickness at the thickest section of the velum was measured on a line perpendicular to the midline during physiological rest.
6. Thickness of the anterior portion of the velum (rest–DE) (function–D′E′). Anterior thickness was measured on a line perpendicular to the midline half the distance between the posterior surface of the posterior nasal spine marker and the posterior surface of the velar eminence marker.
7. Thickness of the posterior portion of the velum (rest–FG) (func-

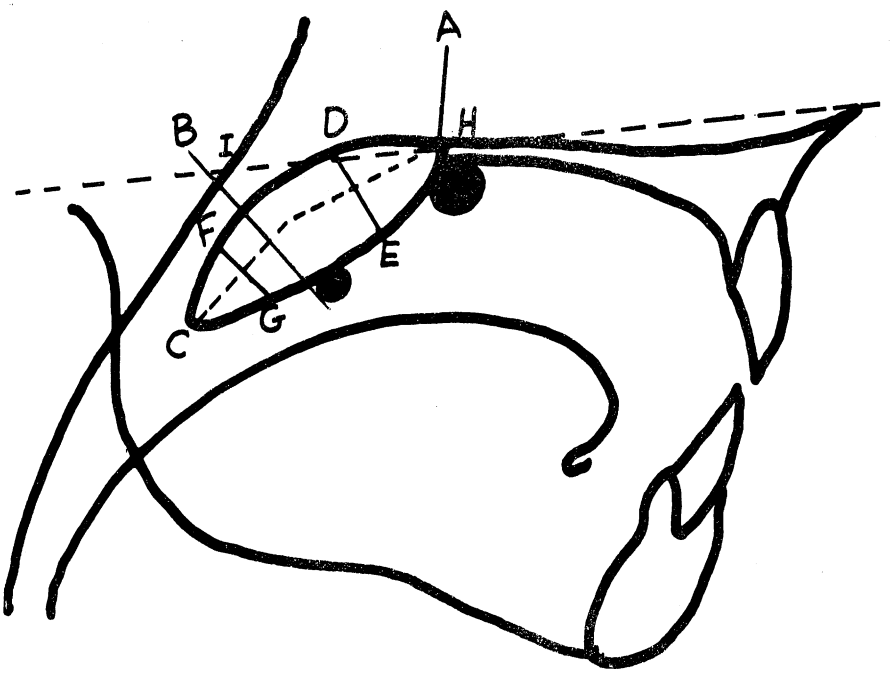

FIGURE 3. Linear measurements taken at physiological rest.

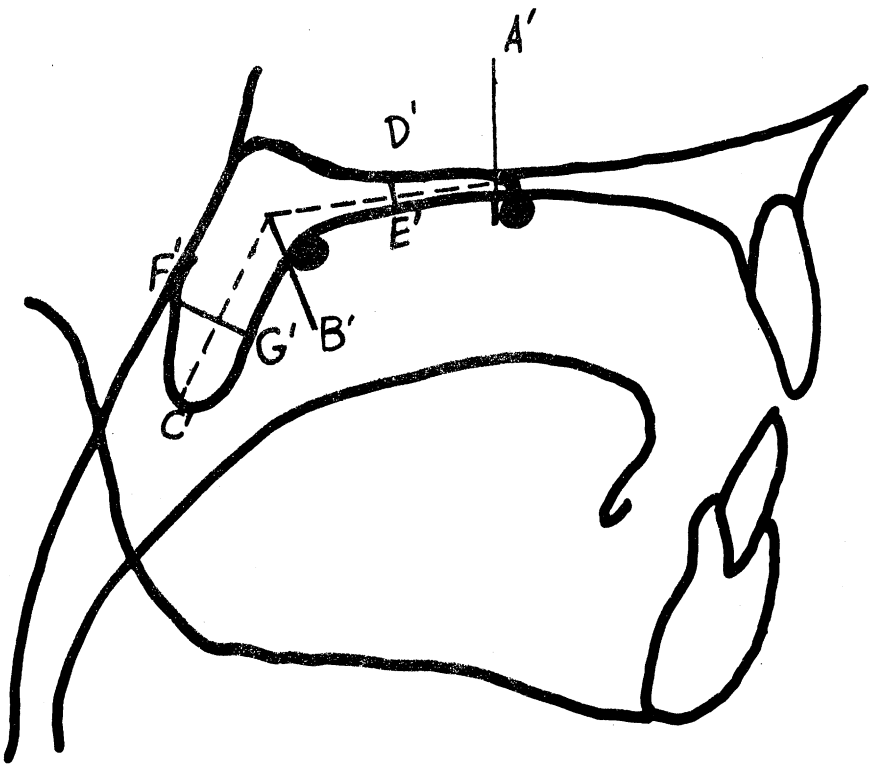

FIGURE 4. Linear velar measurements taken during function

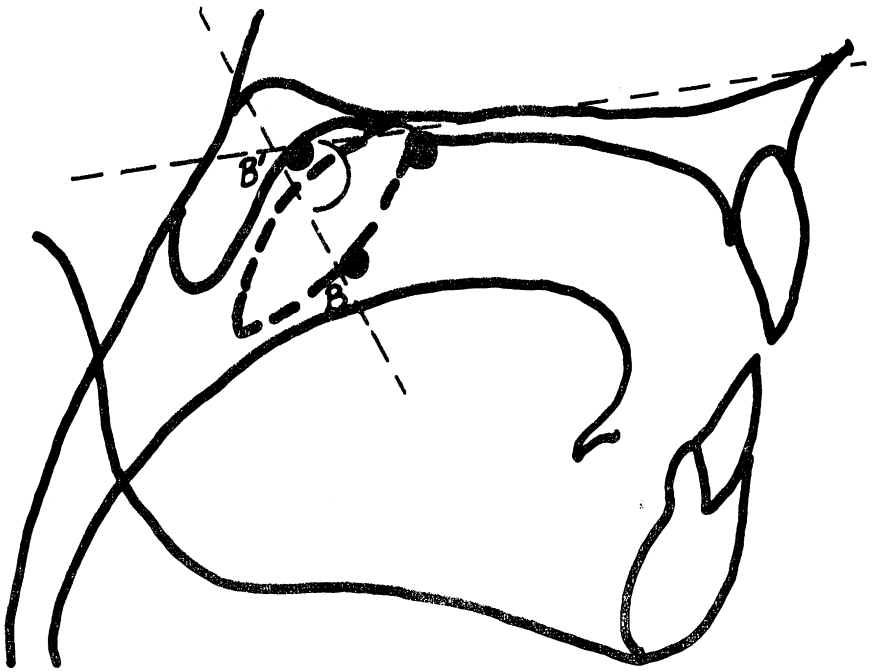

FIGURE 5. Angular measurement of velar movement.

tion–F′G′). Posterior thickness was measured on a line perpendicular to the midline half the distance between the posterior surface of the velar eminence marker and the tip of the uvula.

8. Angle of velar movement (BB′). This angle was the angle formed by the intersection of the palatal plane and a line connecting the posterior surface of the velar eminence markers during physiological rest and function.
9. "Need" ratio (HI/AC). A "need" ratio was computed by dividing the pharyngeal depth by the velar length at rest.

RELIABILITY. In order to assess reliability, all linear measurements were repeated by another investigator. Correlation coefficients were .93 or higher for each of the measures except length of the anterior velar portion and length of the posterior velar portion at rest. These correlations were .80 and .87 respectively. Reliability was considered sufficiently high for the purpose of this study.

Results

As can be seen from Table 1, velar stretch was found in each of the 20 subjects with the mean stretch being 7.35 mm. and a range of 1 mm.–17 mm. This stretch was found to be highly significant at the $p < .001$ level of confidence ($t = 8.405$).

TABLE 1. Means, standard deviations, ranges, and *t* scores of the cephalometric measures. Values are in millimeters unless otherwise indicated.

	mean	*SD*	*range*	*t*
Velar length (rest)	36.70	5.07	23–44	8.405**
Velar length (function)	44.05	6.42	29–58	
Velar stretch	7.35	3.91	1–17	
Length anterior portion (rest)	20.55	3.66	13–24	2.540*
Length anterior portion (function)	22.25	3.79	15–29	
Anterior stretch	1.7	2.99	−4–7	
Length posterior portion (rest)	16.15	3.88	10–22	8.747**
Length posterior portion (function)	21.80	5.03	13–31	
Posterior stretch	5.65	2.88	1–12	
Velar thickness	9.55	1.35	7–12	
Thickness anterior portion (rest)	8.65	1.09	7–11	21.354**
Thickness anterior portion (function)	5.05	.82	4–7	
Change in anterior thickness	3.60	.75	2–5	
Thickness posterior portion (rest)	4.70	1.08	3–6	6.831**
Thickness posterior portion (function)	7.25	1.16	5–10	
Change in posterior thickness	2.55	1.67	0–5	
Pharyngeal depth (rest)	31.95	5.14	19–38	
"Need" ratio (in percent)	87	11	68–119	
Angle of velar movement (in degrees)	54.20	8.57	41–74	

* Significant at less than the .01 level.
** Significant at less than the .001 level.

Behaviors of Each Portion

Through the attachment of the lead markers at the velar eminence, the velum was radiographically divided into an anterior and a posterior portion. In this way, the behaviors of both portions of the velum could be more accurately observed during stretch and possibly provide more information regarding the mechanisms responsible for this stretch. From Table 1 it can be seen that significant stretch was found in both the anterior and the posterior portions of the velum. A significant correlation (Table 2) was found between stretch of the total velum and the stretch in each portion. However, the correlation between stretch in the anterior portion and stretch in the posterior portion did not reach significance. Therefore, the two portions did not behave in a unitary manner. The anterior portion had a mean increase in length of only 1.7 mm. or 9.835% but the posterior portion had a mean increase of 5.65 mm. or 36.02%. This difference in percent of stretch between the two portions was significant at less than the

TABLE 2. Correlation matrix of the linear, angular and derived score measurements.

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*
1	1.000																
2	0.793	1.000															
3	0.648	0.453	1.000														
4	0.690	0.606	−0.102	1.000													
5	0.442	0.622	0.679	−0.063	1.000												
6	0.678	0.807	0.066	0.820	0.039	1.000											
7	0.062	0.033	0.104	−0.024	−0.130	0.140	1.000										
8	−0.375	−0.385	−0.328	−0.164	−0.468	−0.137	0.130	1.000									
9	0.014	0.033	0.031	−0.026	−0.222	0.210	0.885	0.190	1.000								
10	0.655	0.826	0.552	0.332	0.796	0.453	−0.182	−0.315	−0.199	1.000							
11	−0.267	−0.422	−0.002	−0.357	−0.144	−0.430	−0.144	0.041	−0.141	−0.214	1.000						
12	−0.227	0.201	0.033	−0.325	0.567	−0.171	−0.304	−0.029	−0.281	0.584	−0.003	1.000					
13	0.193	−0.000	0.304	−0.052	−0.021	0.015	0.723	0.195	0.632	−0.012	0.073	−0.221	1.000				
14	0.533	0.590	0.534	0.189	0.414	0.440	0.363	−0.105	0.342	0.459	−0.359	0.025	0.479	1.000			
15	−0.256	0.382	−0.256	−0.090	0.341	0.230	−0.038	−0.055	0.018	0.337	−0.288	0.692	−0.287	0.128	1.000		
16	−0.280	0.217	−0.428	0.045	0.357	0.007	−0.215	−0.093	−0.249	0.290	−0.245	0.668	−0.354	−0.019	0.794	1.000	
17	0.021	0.308	0.391	−0.351	0.214	0.231	0.363	0.009	0.437	0.218	−0.065	0.247	0.239	0.481	0.444	−0.139	1.000

Values of $r = \pm.378, \pm.516, \pm.561$ are needed for significance at the .05, .01, and .005 levels, respectively. Linear, angular and derived score measurements used in the correlation matrix were: 1. Velar length at rest. 2. Velar length during function. 3. Length of the anterior portion of the velum at rest. 4. Length of the posterior portion of the velum at rest. 5. Length of the anterior portion of the velum during function. 6. Length of the posterior portion of the velum during function. 7. Thickness of the anterior portion of the velum at rest. 8. Thickness of the posterior portion of the velum at rest. 9. Velar thickness. 10. Pharyngeal depth. 11. Angle of velar movement. 12. "Need" ratio. 13. Thickness of the anterior portion of the velum during function. 14. Thickness of the posterior portion of the velum during function. 15. Percentage of velar stretch. 16. Percentage of velar stretch in the anterior portion. 17. Percentage of velar stretch in the posterior portion.

p .001 level ($t = 4.346$). For those subjects exhibiting stretch of the total velum above the mean, stretch in the anterior portion was always found. For those exhibiting stretch of the total velum below the mean, the anterior portion tended to remain the same or decrease in length with the stretch being a function of the posterior portion.

This difference in stretch between the two portions appeared to be related to the need for the velum to stretch to obtain closure. The subjects were divided into two groups according to the "need" ratio. Ten subjects were below the mean for this ratio and ten subjects were above the mean. For those subjects below the mean, the posterior portion stretched 32.82% with the anterior portion increasing by only 2.18%. However, for those subjects above the mean, the posterior stretched by 39.222% and the anterior portion stretched by 17.49%. Therefore, even though greater stretch occurred in the posterior portion, it would appear that the stretch in the posterior portion is a phenomenon that occurs and is not related to the structural adequacy of the velopharyngeal mechanism. However, stretch in the anterior portion seems to be the adjustment which individuals, who have mechanisms which are less adequate structurally, employ to enable them to achieve velopharyngeal closure. This interpretation is supported by the data in Table 2. The correlation between the percent of stretch in the posterior portion and the "need" ratio was not significant. However, the correlation between stretch in the anterior portion and the "need" ratio was significant beyond the .005 level of confidence.

In terms of thickness, the anterior portion decreased from rest to function with a mean decrease of 3.6 mm. (41.6%). The posterior portion, however, increased in thickness with a mean increase of 2.5 mm. (54.3%). Thus the anterior portion increased in terms of length but decreased in thickness. The posterior portion increased in length and also in thickness.

Stretch and Clinical Cephalometric Measures

The correlation matrix (Table 2) was obtained in order to see if there were significant correlations between the amount of stretch and other commonly employed cephalometric measures. If significant correlations could be found then some direction might be obtained for determining structural characteristics which would be consonant with velar stretch.

The correlation between the amount of stretch and velar length at rest did not prove to be significant. The fact that this was a negative correlation indicated the trend for a greater stretch to occur in those individuals with a short velum. Also, the correlation between the amount of velar stretch and pharyngeal depth was not significant. However, when these two measures were combined into the "need" ratio, the correlation was found to be significant at the $p < .0005$ level. Since all the subjects had normal articulation and resonance balance, this finding was not surprising. It does indicate that velar stretch is one of the adjustment mechanisms used by individuals to enable them to obtain closure.

The correlation between the amount of velar stretch and velar thickness was extremely low, and for prognostic purposes, this specific measure seems to have little value. The correlation between velar stretch and angle of velar movement also did not reach statistical significance. Although this relationship is suggestive that the more acute the angle formed the greater the velar stretch, the correlation was not sufficient to warrant a more definite conclusion.

Discussion. In order to learn more about the mechanism or mechanisms responsible for velar stretch, it was decided that the velum must be separated into an anterior and posterior portion. The marker to delineate the portion had to (1) be readily observable on lateral radiographs; (2) be sufficiently stable to prevent movement; (3) be non-irritating to the subject; and (4) be of minimal weight so that the marker would not restrict velar movement. Many methods were attempted which were not satisfactory. The lead spheres met all four criteria. These were readily visible on the radiographs and were generally stable. In a few subjects, the marker was found to move and the resulting radiographs were not used in the study. Most of the subjects had no awareness of the marker after it had been placed. The only negative reaction was to the taste and consistency of the dental adhesive after the markers had been removed.

It was not surprising to find velar stretch in normal subjects since this had been reported by previous investigators. The obtained percentage of velar stretch was at variance with earlier findings (*1, 8*) but this finding may be attributed to variations in the experimental procedures.

The finding that the posterior portion of the velum exhibits a greater increase in length than the anterior portion was somewhat surprising. It had been assumed that the major increase in length would occur in the anterior portion of the velum as a result of the levator muscles pulling posteriorly away from the anterior velar attachment. This activity probably did account for a portion of the stretch for the increase in length and decrease in thickness of the anterior portion would be consonant with this theory. The same type of activity may also account for the increase in length of the posterior portion of the velum. It is possible that the posterior portion is also "fixed" by the action of the palatopharyngeus and palatoglossus muscles. If this is true, then the stretch of the posterior portion could also be the result of levator action against a "fixed" attachment.

Change in thickness of the posterior portion may be a paradox for this portion of the velum not only increased in length but also increased in thickness. This increased thickness in function could be the result of the uvular muscle. Pigott (*7*) using a nasendoscopic approach state that the bulk of the musculous uvulae could be seen as a "large ridge down the soft palate, occupying the central one-third, rising to a height almost equal to its width." During speech, the "levator sling could be seen to tighten into a bar, throwing the convexity of the muscular uvulae bulge up and back

to fit in the concavity of the posterior superior pharyngeal wall." Thus, this activity could account for the apparent increase in thickness during function.

The need for additional information is obvious. One of the obvious needs is for longitudinal data regarding this adjustment mechanism. Ideally, this longitudinal data would be accumulated on both normal subjects and subjects with various types of clefts or velopharyngeal inadequacies. Another obvious need is for electromyographic information related to this stretch phenomenon. The goal is still to develop a thorough understanding of velar stretch so that stretch potential can be predicted for a specific individual. This goal has certainly not been achieved in this study but perhaps it has taken a step in this direction.

SUMMARY. Velar stretch was examined in twenty normal adult speakers for the purpose of determining some of the characteristics of this adjustment activity. The velum was divided into an anterior portion and a posterior portion by the placement of lead markers at the posterior nasal spine and the levator eminence. Cephalometric x-rays were taken at physiological rest and during the production of a sustained /s/.

Significant stretch was found for the entire velum and for each of the portions with the posterior portion exhibiting a greater amount of stretch than the anterior portion. There were also changes in thickness of each portion. As the anterior portion increased in length, it decreased in thickness. As the posterior portion increased in length, it increased in thickness.

Correlations between velar stretch and the usual clinical cephalometric measures were also determined. The only correlation which was statistically significant was between velar stretch and the "need" ratio.

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