The Sphincteric Mechanism of Velopharyngeal Closure

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A complete understanding of the mechanics of velopharyngeal closure is essential for the development and selection of adequate methods of treating patients with velopharyngeal incompetence. The mechanism of velopharyngeal closure still appears to be poorly understood. Until very recently, the emphasis in the literature has been on velar movement because this type of movement is easiest to radiographically demonstrate with traditional lateral views of the nasopharynx. The importance of lateral pharyngeal wall movement in velopharyngeal closure (*1, 3, 5, 9*) and particularly in patients with pharyngeal flaps (*4, 7, 8*), has been recently stressed in the literature. However, we believe that concepts which view velopharyngeal closure as resulting from a combination of velar (flap valve) and lateral pharyngeal wall movement are only partially correct.

On the basis of the studies presented in this paper, it appears that the mechanism of velopharyngeal closure is really a sphincteric one. Although this concept of closure has been previously described in the literature (*2, 10*), it is poorly appreciated because of the difficulty in visualizing the velopharyngeal portal in the manner necessary to show the sphincteric movements. This paper will describe the various patterns and configurations that the sphincteric mechanism exhibits in a group of eighty-five non-nasal and nasal subjects without pharyngeal flaps. These patients were studied with our previously described multi-view videofluoroscopic techniques (*6*). The patients were examined in the lateral, base and usually the frontal view after the nasopharynx was coated with barium.

General Observations

To facilitate description of the sphincteric mechanism of velopharyngeal closure we have divided it into two components, the velar and pharyngeal ones. The velar component refers to the movements of velum elevation and posterior elongation. The velum forms the anterior margin of the sphincteric mechanism. The pharyngeal component which forms the balance of the velopharyngeal sphincter includes all movements of the nasopharyngeal wall. No attempt is made to distinguish between the

Paper was presented at the 1972 meeting of the American Cleft Palate Association.
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lateral and posterior aspects of the pharyngeal wall because in most instances they do not appear radiographically to be distinct and separate moving structures on the base view. Rather the nasopharyngeal wall seems to move as a single functional unit. Furthermore, there is really no precise fluoroscopic demarcation between the lateral aspects of the velum and the beginnings of the pharyngeal wall. They just merge together.

Figure 1 is a schematic illustration of the mechanics of velopharyngeal closure in the normal subject as viewed radiographically in the lateral, frontal and base views. Observe on the lateral view that the velum elevates and elongates posteriorly during phonation. This view shows only the mid-sagittal relationship between the velum and the posterior aspects of the pharyngeal wall. On the frontal view, the lateral aspects of the nasopharyngeal wall do appear to be distinct, parallel structures that move medially during phonation. However, examination of the base view reveals the lateral pharyngeal walls to be only the most lateral aspects of an oval sphincter that is medially contracting. Since the x-ray beam projects only that portion of the barium coated portal that is hit tangentially, the lateral aspects of the pharyngeal wall erroneously appear on

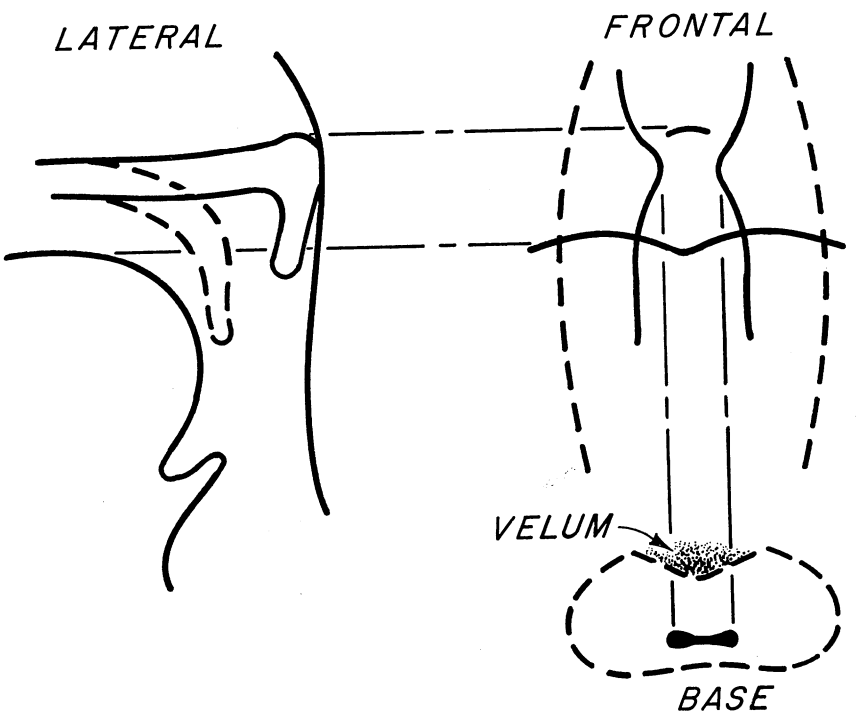


FIGURE 1. Schematic view of pharynx of a normal subject showing sphincteric mechanism of velopharyngeal closure from the lateral, frontal and base radiographic projections. The dotted lines represent position of velum and pharyngeal walls at rest; heavy solid lines of same structures show their positions during velopharyngeal closure.

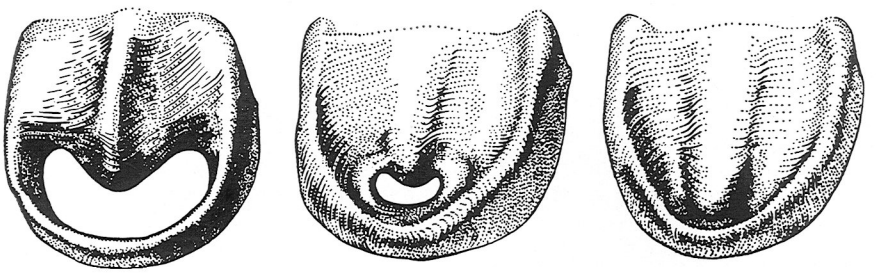


FIGURE 2. Sketches of sphincteric closure of velopharyngeal portal in a normal subject seen from base view. Left sketch: Portal at rest. Middle sketch: Portal during partial closure. Note that a coronal pattern is developing as velum moves posteriorly and pharyngeal walls contract centrally. Right sketch: Full closure has occurred producing coronally oriented slit.

the frontal view as distinct and separate vertical structures. It should be emphasized that the frontal view is useful because it best demonstrates the vertical extent of the pharyngeal portion of the velopharyngeal sphincter. However, the base view which permits visualization of the portal en face is required to appreciate the total sphincteric concept of velopharyngeal closure.

The base view illustration in Figure 2 further elucidates the above concepts schematically. Notice how the margins of the velopharyngeal portal progressively move centrally during phonation. The final closure pattern in the normal subject is a coronally oriented slit. Observe that the lateral pharyngeal walls do not exist as distinct, separate structures but are merely the lateral aspects of the margins of the pharyngeal component of the velopharyngeal sphincter.

Multiple Sphincteric Patterns of Velopharyngeal Closure

In both non-nasal and nasal subjects, we have found multiple patterns of sphincteric closure attempted closure of the velopharyngeal portal. The division of the closure mechanism into velar and pharyngeal components is very useful in understanding the differences in these closure patterns. The multiple patterns result from variations in the relative contribution of the velar and pharyngeal component movements to the closure mechanism.

VELOPHARYNGEAL COMPETENCE. The several variations in the sphincteric pattern of velopharyngeal closure that we have observed in subjects with competent closure mechanisms are illustrated schematically in Figure 3. Actual data in the form of photographs of the TV monitor taken during stop framing of the video tape recorder are presented in Figures 4–6 to further illustrate some of these sphincteric patterns.

The final closure pattern in a normal subject generally appears on the base view of the velopharyngeal portal as a coronally oriented slit (Figures 3A and 4). A similar closure pattern is frequently seen in patients

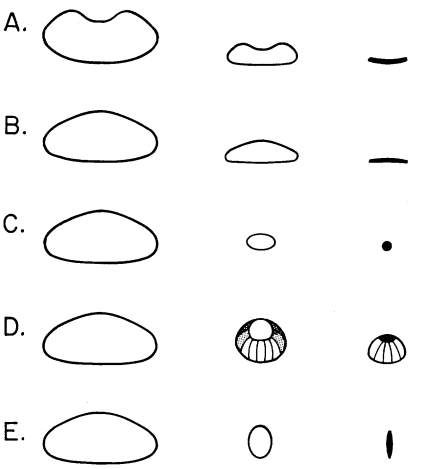


FIGURE 3. Left column represents contour of velopharyngeal portal at rest, middle column shows partial closure, right column is at full closure. A. Normal subject. Note convex projection of uvula portion of velum into velopharyngeal portal at rest. B. Repaired cleft palate subject. Note absence of uvula muscular bulge at rest. Pattern of closure is coronal, similar to normal subject in A. C. Repaired cleft palate with circular closure pattern. D. Repaired cleft palate with circular closure pattern and Passavant's ridge. Ridge is represented by stippled and lined area in middle and extreme right columns. E. Repaired cleft palate with sagittal closure pattern.

with a repaired cleft palate (Figure 3B). The contributions of the velar and pharyngeal components of sphincteric closure in these individuals appear to be relatively equal.

Some patients with or without repaired cleft palates who exhibit either a foreshortened velum or decreased velar elevation and elongation still achieve velopharyngeal closure during speech. This appears to be accomplished in these patients by an increased contribution of the pharyngeal component of the sphincteric closure mechanism. Some of these individuals show a circular closure pattern on base view videofluorography (Figures 3C and 5). Among the individuals who show a circular closure pattern are those patients who exhibit a Passavant's pad (Figure 3D). Some patients who accomplish velopharyngeal closure in association with increased movement of the pharyngeal component of the velopharyngeal sphincter show a sagittally oriented slit on base view videofluorography (Figures 3E and 6). This radiographic image is formed by the meeting of the lateral aspects of the pharyngeal wall in midline. The palate abutts against the central bulge formed by the approximated lateral aspects of the pharyngeal wall.

Of the eighty-five patients without pharyngeal flaps who were examined in this study, twenty-three exhibited fluoroscopic evidence of velopharyngeal competence. Fourteen patients showed the "normal" coronally oriented closure pattern (Figures 3A and 3B). A circular closure pattern (Figures 3C and 3D) was observed in eight individuals; four of these patients exhibited a Passavant's pad (Figure 3D). Only one of the twenty-three patients in this study with velopharyngeal competence showed a sagittally oriented closure pattern (Figure 3E).

VELOPHARYNGEAL INCOMPETENCE. The number of patterns of attempted sphincteric closure of the velopharyngeal portal observed in patients with *incompetent* closure mechanisms is greater than that seen in patients with

FIGURE 4A

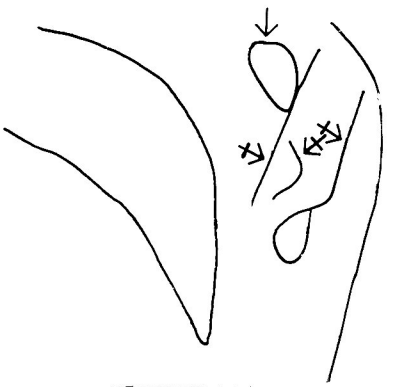


FIGURE 4AA

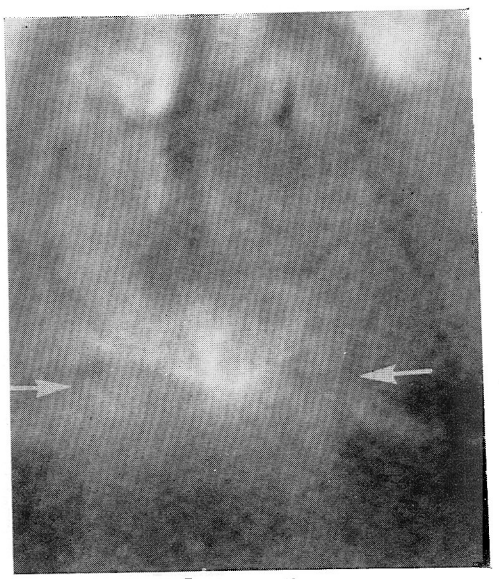


FIGURE 4B

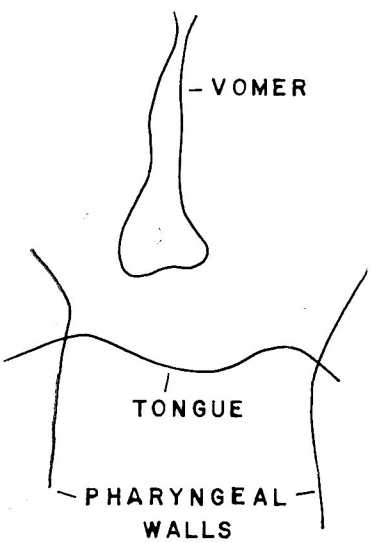


FIGURE 4BB

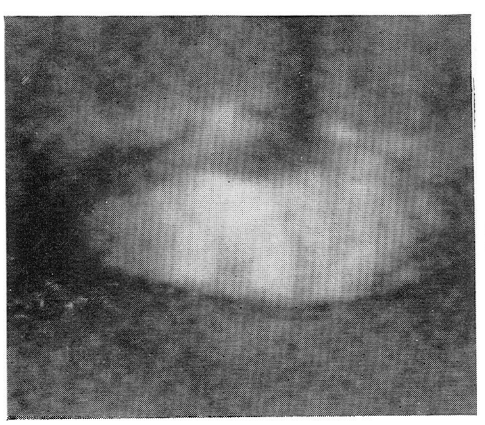


FIGURE 4C

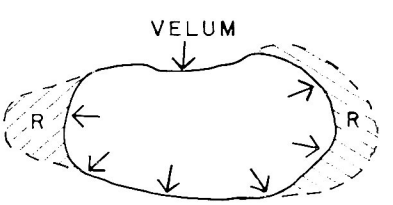


FIGURE 4CC

FIGURE 4. Normal subject during breathing and phonation in lateral, (A-AA, D-DD), frontal (B-BB, E-EE), and base (C-CC, F-FF) projections. (→ ←) lateral aspects of pharyngeal sphincter on frontal view; (↓ ↓) region of coronal closure on base view. Key to sketches: ↓, Torus; ‡, Barium coating mucous in nasopharynx, ⇇, Barium in Rosenmuller's fossa; R, Rosenmuller's fossa; ⇆ ↓ ⇄, Pharyngeal walls on base view.

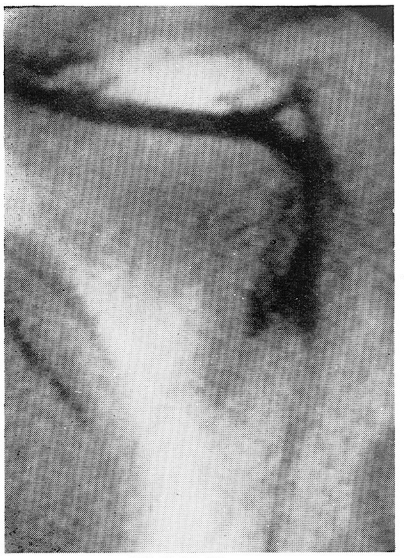


FIGURE 4D

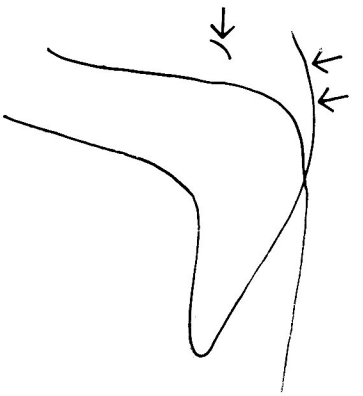


FIGURE 4DD

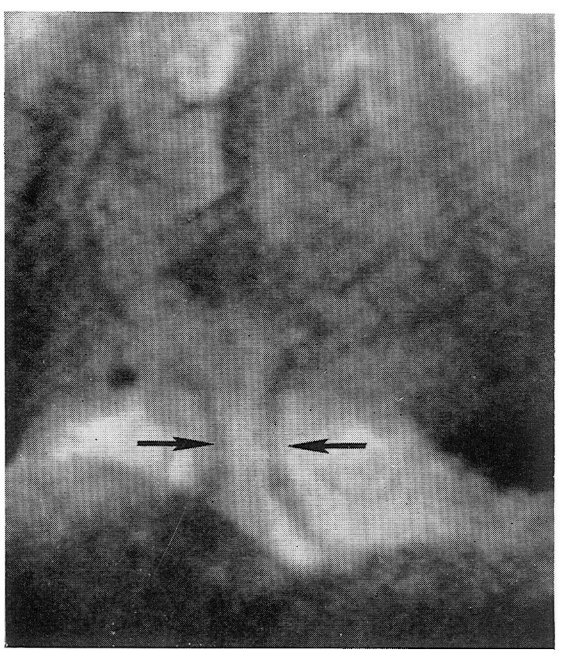


FIGURE 4E

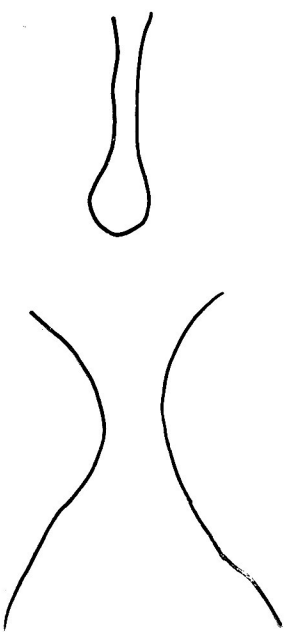


FIGURE 4EE

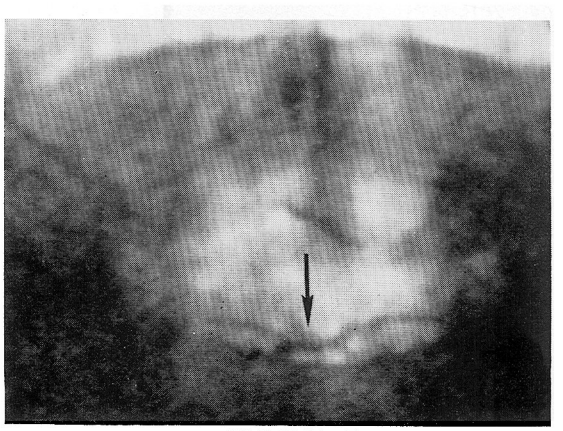


FIGURE 4F

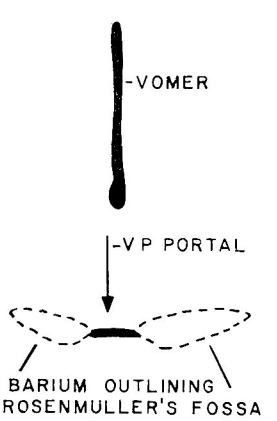


FIGURE 4FF

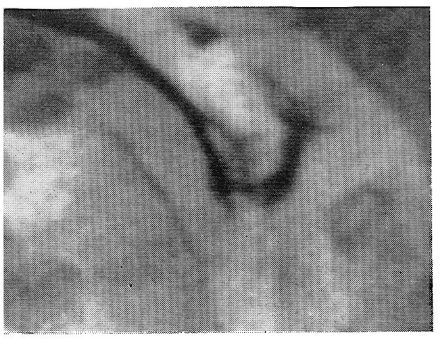


FIGURE 5A

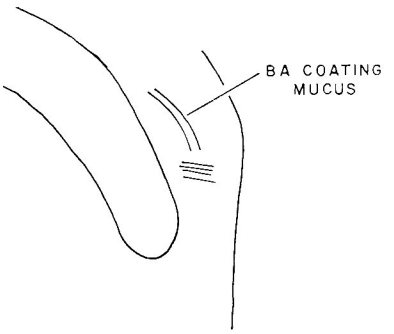


FIGURE 5AA

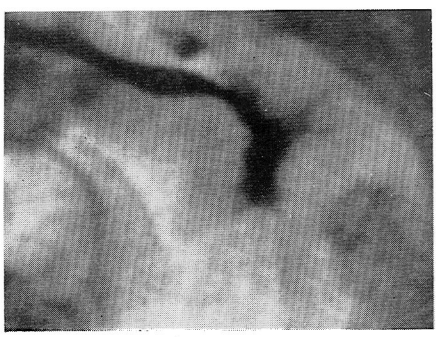


FIGURE 5B

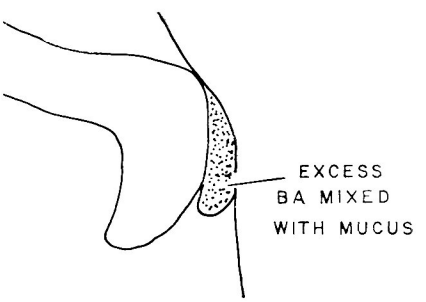


FIGURE 5BB

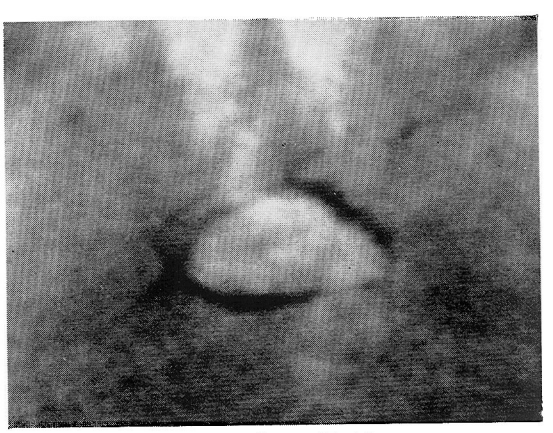


FIGURE 5C

FIGURE 5. Repaired cleft palate subject with circular pattern of velopharyngeal closure. The lateral and base views during breathing (A-AA, C) and phonation (B-BB, E-EE). D-DD is the base view during partial closure to better demonstrate circular pattern of sphincteric closure. At stage E, complete closure has occurred and barium is smudged (EE, ⁘) so actual circular closure pattern is obscured. On DD and EE the outline of the vomer is shown above the sphincter.

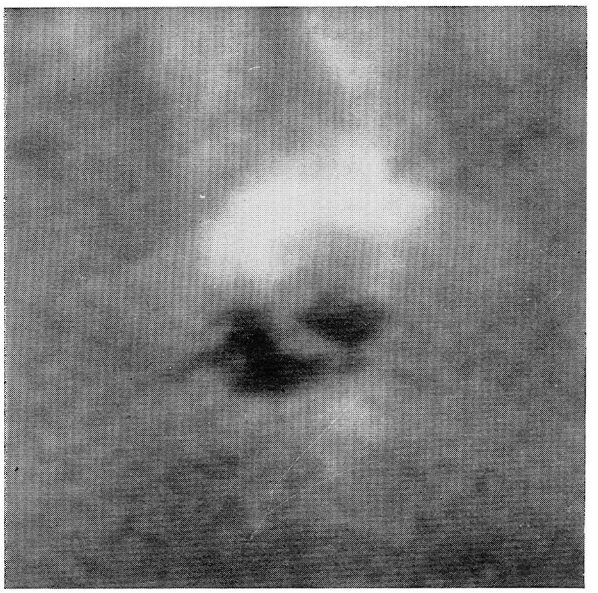


FIGURE 5D

FIGURE 5DD

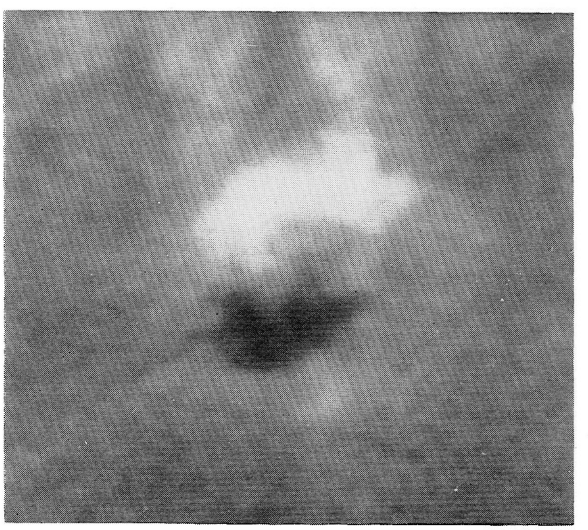


FIGURE 5E

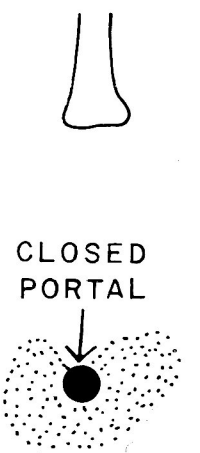


FIGURE 5EE

velopharyngeal *competence*. The sphincteric patterns of attempted closure in the incompetent group include those seen in persons with velopharyngeal competence; however, there are additional patterns that occur as well. Variability appears to be the rule rather than the exception.

Figure 7 schematically illustrates the multiple sphincteric patterns of attempted closure of the velopharyngeal portal that we have observed in

FIGURE 6A

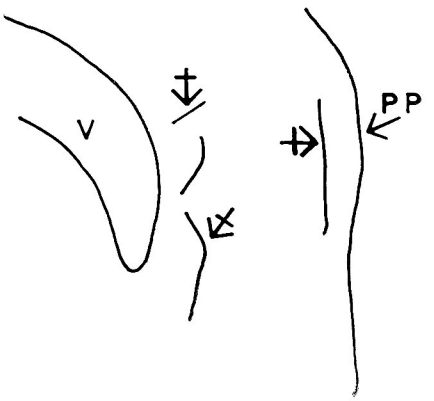


FIGURE 6AA

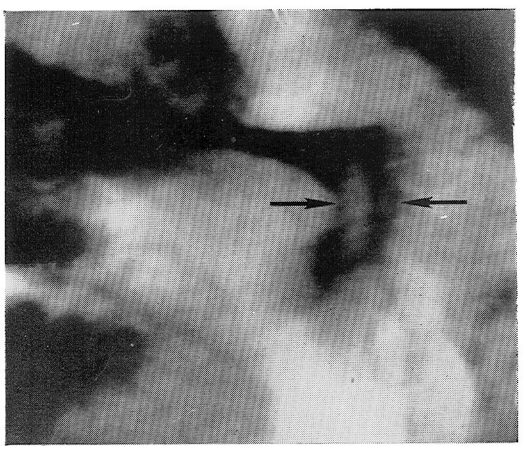


FIGURE 6B

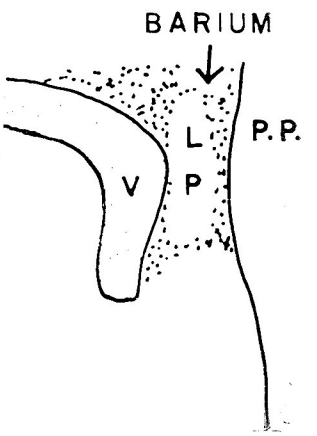


FIGURE 6B

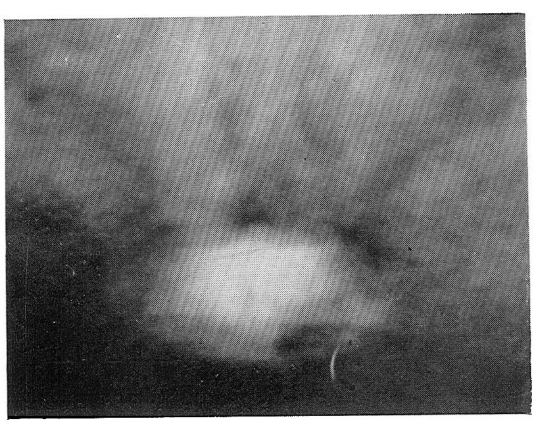
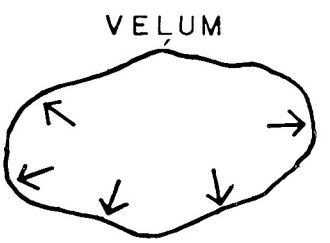


FIGURE 6C



FIGURG 6CC

FIGURE 6. Repaired cleft palate with sagittal closure pattern. Lateral and base during breathing (A-AA, C-CC) and phonation (B-BB, D-DD). In the lateral view during phonation (B) the posterior edge of the velum (→) does not touch the posterior pharyngeal wall (←); a soft tissue mass (BB-LP) is interposed between the velum and posterior pharyngeal wall. The base view during phonation (D-DD) shows the mass to result from the apposition of the pharyngeal walls (LP → ← LP) to produce a sagittally oriented slit. Key to sketches: ‡ Barium coating mucous; V, Velum; LP, Lateral aspects of pharyngeal walls; PP, Posterior aspect of pharyngeal walls; ⇆↓⇆, Pharyngeal walls on base view.

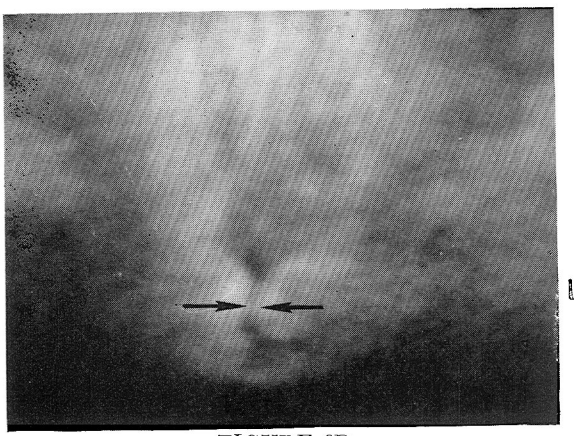


FIGURE 6D

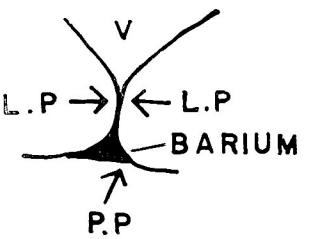


FIGURE DD

patients with velopharyngeal incompetence. Again, some of these sphincteric patterns are further illustrated in Figures 8–11 by photographs of actual data.

Patients with velopharyngeal incompetence may show little movement of the velar and pharyngeal components of closure (Figures 7A and 8). In contrast, other patients may exhibit good velar elevation and elongation, but little or no movement in the pharyngeal component of sphincteric closure (Figures 7B and 9). Neither of these two patterns have been observed in patients with competent velopharyngeal mechanisms.

The more normal sphincteric pattern of velopharyngeal valving is illustrated in Figure 7C. Although the contributions of the velar and pharyngeal components of closure appear to be relatively equal, the degree of movement in both components is reduced and insufficient to achieve velopharyngeal competence. A coronally oriented oval is observed on the base view of the velopharyngeal portal.

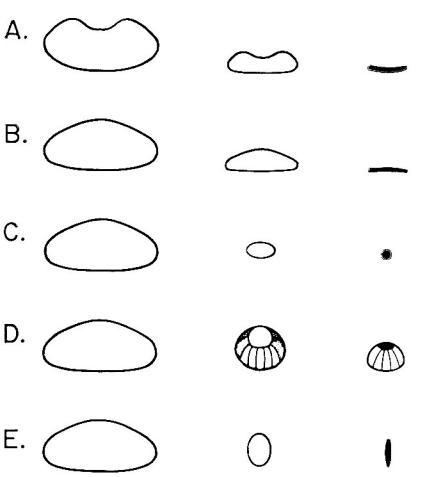


FIGURE 7. Left hand column represents portal at rest, middle column during partial closure, and right hand column at maximum closure. A. Subject with almost no velar or pharyngeal wall movement. B. Subject post adenoidectomy with good velar but almost no pharyngeal wall movement. C. Normal coronal pattern of portal narrowing in which both velar and pharyngeal walls contribute equally but neither moves sufficiently to produce closure. D. Circular narrowing pattern without Passavant's ridge. E. Circular narrowing pattern with Passavant's ridge (line areas in middle and right column). F. Sagittal narrowing pattern.

FIGURE 8A

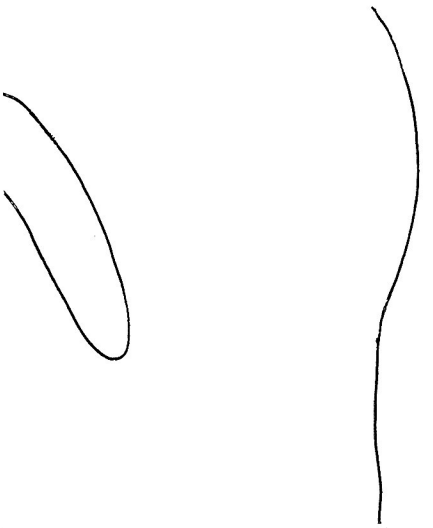


FIGURE 8AA

FIGURE 8B

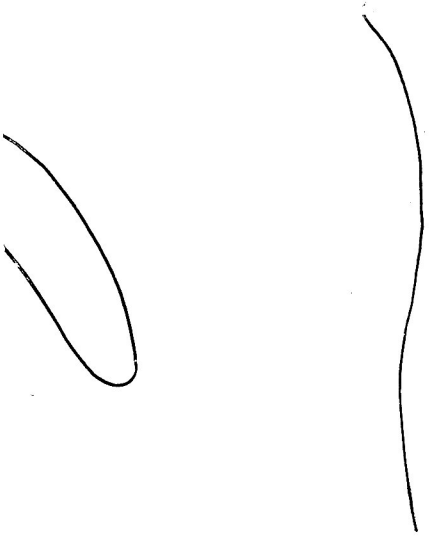


FIGURE 8BB

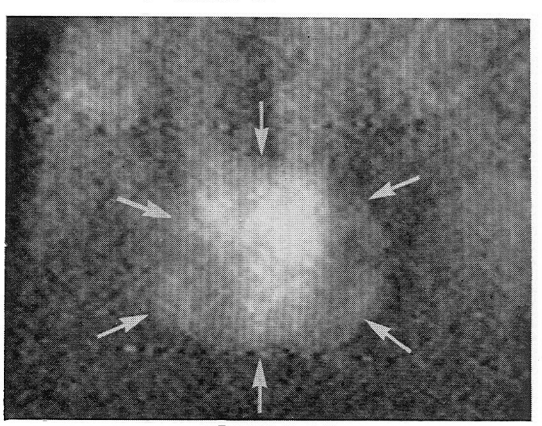


FIGURE 8C

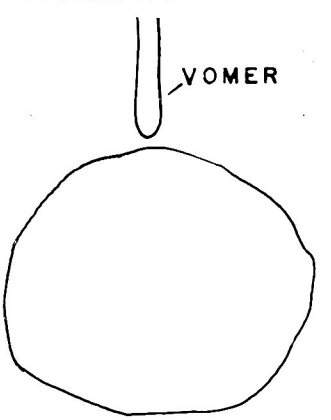


FIGURE 8CC

FIGURE 8. Repaired cleft palate subject with no significant velar or pharyngeal muscle movements. Lateral and base views during breathing (A-AA, C-CC) and phonation (B-BB, D-DD). Arrows indicate margins of portal on base view.

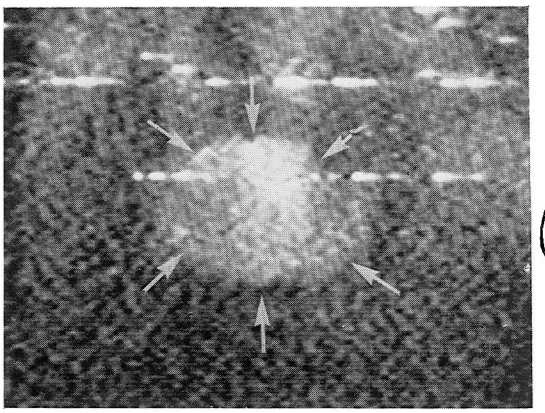


FIGURE 8D

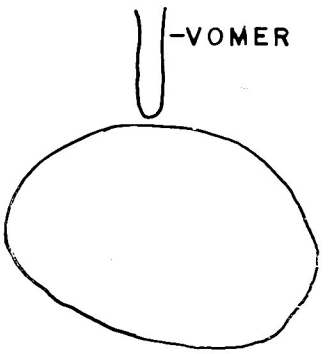


FIGURE 8DD

Patients with velopharyngeal incompetence may show evidence of an increased contribution of the pharyngeal component of the sphincteric closure mechanism in probable compensation for a deficiency in the velar component of closure. Most of these individuals will exhibit a circular pattern of attempted closure of the velopharyngeal portal on base view videofluorography (Figures 7D and 10). Again, the circular closure pattern in some of the patients is associated with the presence of a Passavant's pad (Figure 7E). As can be observed in Figure 11, the Passavant's pad is formed as a crescent shaped bulging of the entire nasopharyngeal wall. Some patients with a marked deficiency in the velar component of velopharyngeal closure will exhibit an apparent compensatory increase in the movement of the pharyngeal component of closure that results in a sagittal rather than circular narrowing of the velopharyngeal portal. Velopharyngeal incompetence in this situation manifests itself on base view videofluorography as an sagittally oriented oval (Figure 7F).

Sixty-two of the eighty-five patients examined in this study exhibited fluoroscopic evidence of at least some degree of velopharyngeal incompetence. Nine patients showed no or very poor movement of the velar and pharyngeal components of closure (Figure 7A). Two patients exhibited good velar movement but no or very poor movement of the pharyngeal component (Figure 7B). The more normal appearing coronal narrowing sphincter pattern was observed in fourteen individuals (Figure 7C). Twenty-eight of the patients showed one of the circular narrowing patterns (Figures 7D and 7E); seventeen of these individuals exhibited a Passavant's pad (Figure 7E). A sagittally oriented pattern of attempted closure was seen in four patients (Figure 7F). The behavior of the velopharyngeal valving mechanism in five persons was inconsistent or showed variations in the sphincteric pattern of attempted closure for different speech sounds.

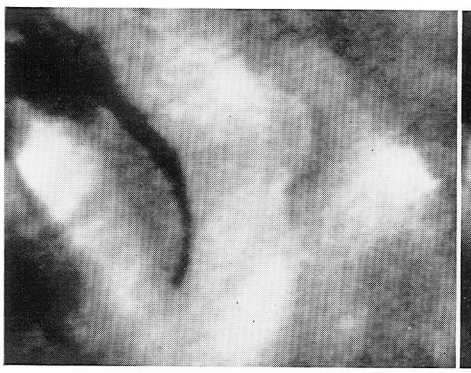


FIGURE 9A

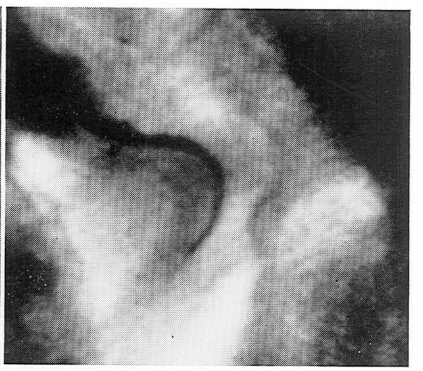


FIGURE 9B

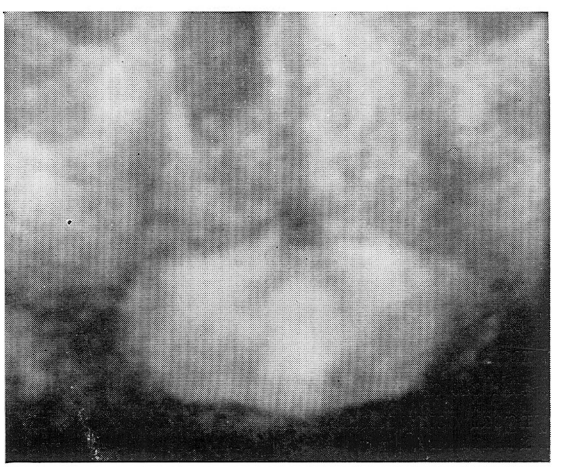


FIGURE 9C

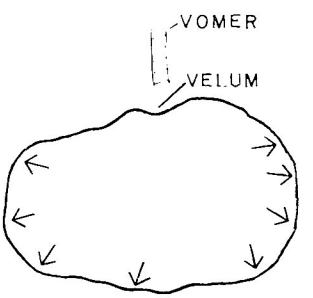


FIGURE 9CC

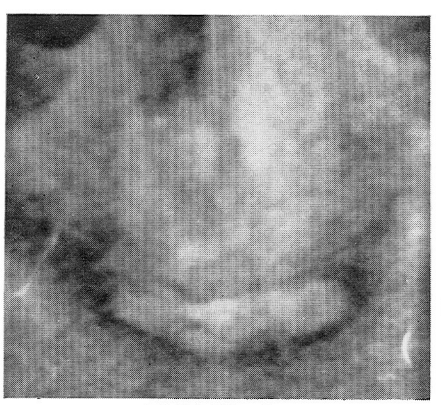


FIGURE 9D

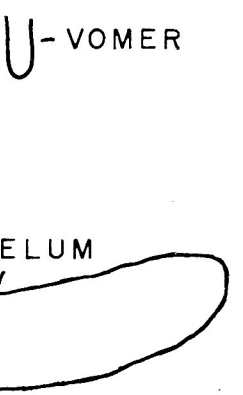


FIGURE 9DD

FIGURE 9. Patient post adenoidectomy with good velar but almost no pharyngeal wall movements. Lateral and base views during breathing (A, C-CC) and phonation (B, D-DD). ↖↑↗ ←↓→, Pharyngeal walls on base view during quiet breathing.

Discussion

With more adequate procedures for the study of the velopharyngeal mechanism, information concerning a variety of defects in the closure mechanism that contribute to velopharyngeal incompetence can be obtained. The ability to observe physiological variations such as those described in this article poses a two-fold challenge to professionals involved in the habilitation of patients with velopharyngeal incompetence.

The *first challenge* is for each professional to assess the limitations in his current procedures for the clinical evaluation of the mechanism of velopharyngeal closure and to supplement his procedures with more adequate techniques such as multiview video or cinefluorography when possible. In this regard, it seems appropriate to emphasize that the articulatory and resonance characteristics of a patient's speech are valid indicators only of (1) the presence or absence of velopharyngeal incompetence and (2) the consistency or inconsistency of the incompetence. The speech symptoms provide no information about the precise defects in a patient's velopharyngeal mechanism that is producing his incompetence. We believe it is vital to know these precise defect(s) in a given patient's velopharyngeal closure mechanism prior to undertaking procedures to correct the abnormalities producing the deviant speech, whether by surgery, prosthetic devices or speech therapy. Only by this means can the treatment be adequately tailored to the needs of an individual patient and the results then objectively assessed.

It should be emphasized that the standard oral examination procedure employed by the plastic surgeon and speech pathologist frequently is limited. Judgments of the length of the palate relative to the depth of the nasopharynx can be in error. The epipharynx, which is really the area of interest, is known to vary considerably in height, depth and configuration; it is above the level of view through the mouth.

Judgments of the mobility of the velar and pharyngeal musculature are likewise subject to error. First of all, the critical mesial movement of the pharyngeal musculature involved in velopharyngeal closure occurs at a level above that which can be visualized through the mouth. As a rule of thumb, if you observe active movement of the velar and pharyngeal musculature during an oral examination, it is highly probable that the musculature is actively mobile during at least a portion of a patient's conversational speech. However, if you observe little or no movement of the velar or pharyngeal musculature during an oral examination, there may or may not be limited movement of the velopharyngeal musculature during conversational speech; you just don't know. Furthermore, direct visualization does not permit an assessment of the degree of relative contribution of the velar and pharyngeal components to the total sphincteric mechanism of velopharyngeal closure. Kelsey and his colleagues (4) have demonstrated that the degree of movement in the pharyngeal compo-

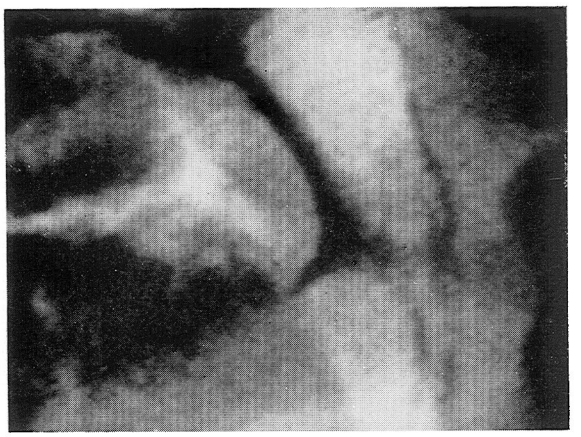


FIGURE 10A

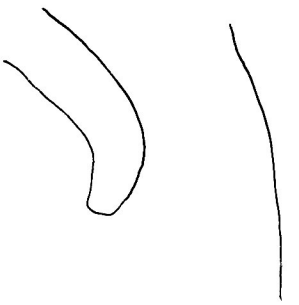


FIGURE 10AA

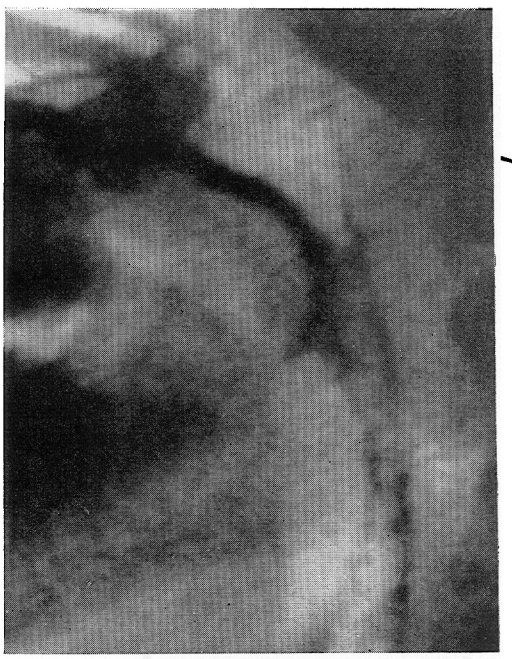


FIGURE 10B

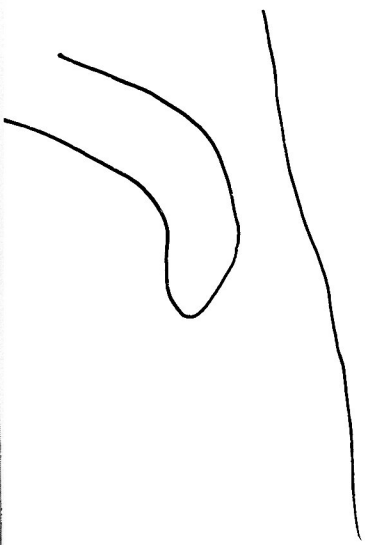


FIGURE 10BB

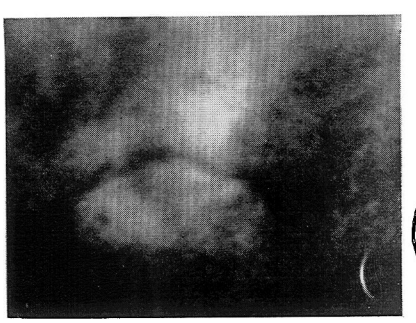


FIGURE 10C

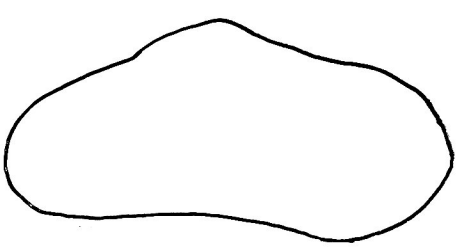


FIGURE 10CC

FIGURE 10. Repaired cleft palate patient with circular narrowing pattern. Lateral and base views during breathing (A-AA, C-CC) and phonation (B-BB, D-DD).

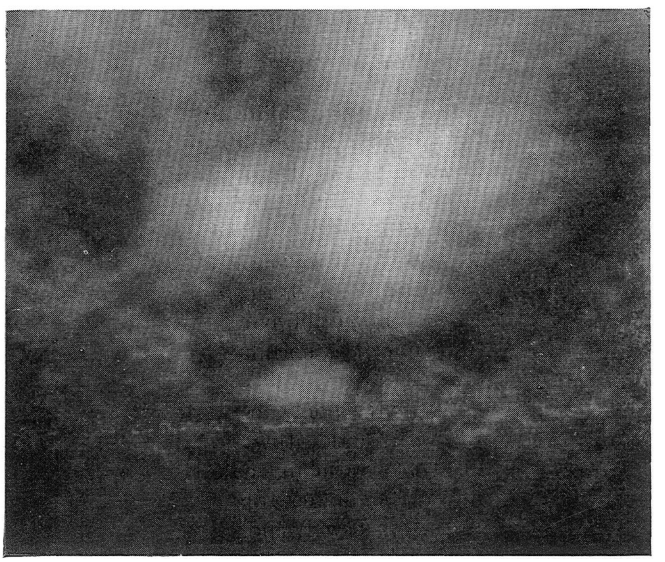


FIGURE 10D

FIGURE 10DD

nent of velopharyngeal closure has predictive value for surgical success in the treatment of patients with velopharyngeal incompetence.

As should be apparent from the data presented here, the traditional lateral x-ray of the nasopharynx is a very limited procedure by itself for the examination of the velopharyngeal closure mechanism. To be adequate, a roentgen examination procedure must be capable of defining the precise defect in a patient's closure mechanism that is producing his velopharyngeal incompetence. At present, we believe the velopharyngeal portal should be radiographically examined by techniques that simultaneously record movement and speech and sequentially in multiple projections. Either cine with sound synchronization or video tape is applicable. We are utilizing a lateral view to show the mid-sagittal movements of velum elevation and elongation and, at times, anterior movement of the posterior pharyngeal wall. A frontal view best demonstrates the vertical length of the lateral aspects of the moving pharyngeal walls and when used with the lateral view also demonstrates the relationship of the velar eminence to the region of maximum movement of the lateral aspects of the pharyngeal wall. The base view, which visualizes the velopharyngeal portal en face, shows the relationship of the velum and lateral/posterior aspects of the pharyngeal wall to each other and thus elucidates the mechanics of the entire sphincteric mechanism of velopharyngeal closure.

The *second challenge* that we visualize for professionals involved in the habilitation of patients with velopharyngeal incompetence is to utilize available procedures more selectively as well as to develop new procedures that are more appropriate for the remediation of the specific problems of

FIGURE 11A

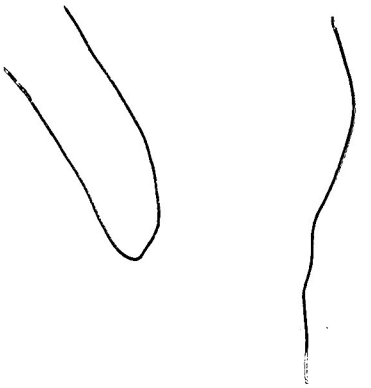


FIGURE 11AA

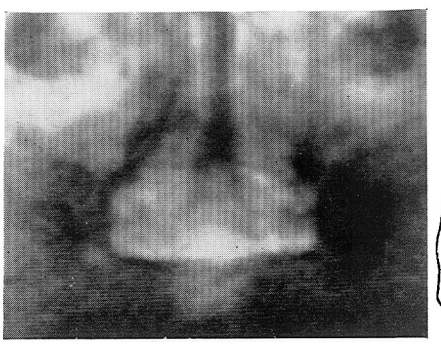


FIGURE 11B

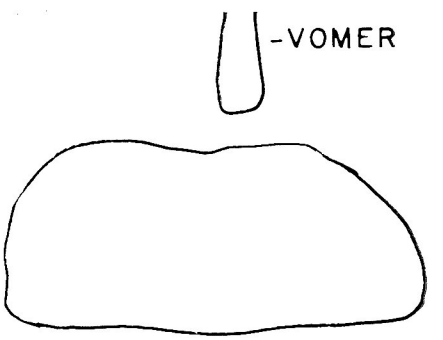


FIGURE 11BB

FIGURE 11C

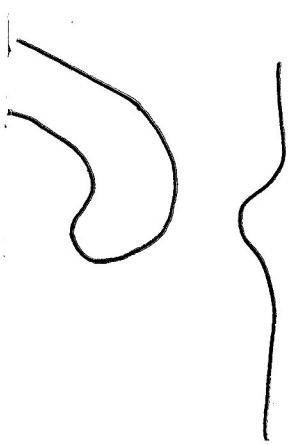


FIGURE 11CC

FIGURE 11. Repaired cleft palate with velopharyngeal incompetence and circular closure pattern containing Passavant's ridge. Lateral and base views during breathing (A-AA, B-BB) and phonation (C-CC, D-DD). Opposing arrows and arrow heads (↑ ↑ ↑), Passavant's ridge on base view during phonation. (←), Passavant's ridge, lateral view.

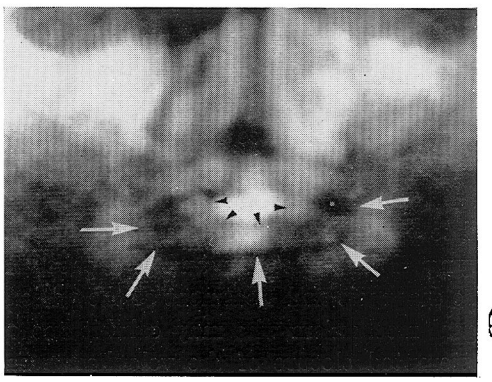


FIGURE 11D

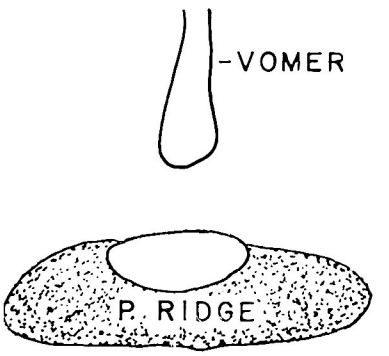


FIGURE 11DD

patients with velopharyngeal incompetence who exhibit multiple sphincteric patterns of attempted closure of the velopharyngeal portal. Can the speech pathologist or prosthodontist improve his success in stimulating increased activity of the velar and pharyngeal musculature of the patient with poor mobility of both components of the sphincteric mechanism of velopharyngeal closure (Figure 8)? Should procedures be different for the patient who has good mobility of the velum but limited movement of the pharyngeal component of velopharyngeal closure (Figure 9)? Can the surgeon who uses the pharyngeal flap as a secondary surgical procedure be successful in systematically varying the width of his flap to better meet the specific needs of the patient with poor mesial movement of the pharyngeal musculature (Figures 8, 9) as compared to the patient with good pharyngeal muscle movement (Figures 10, 11)? Or should a different procedure other than the pharyngeal flap be used in this latter situation so as to better insure the prevention of possible unnecessary nasopharyngeal obstruction with associated denasality? Abnormalities of flap width relative to the extent of mesial movement of the pharyngeal wall have been cited by the present authors (7) as one of the frequent contributors to persistent problems in velopharyngeal valving following pharyngeal flap surgery. Among the other frequent contributors to persistent velopharyngeal incompetence in patients with a pharyngeal flap are abnormalities of (1) flap position in relation to the lateral aspects of the pharyngeal wall on the horizontal plane and (2) flap level vertically in the nasopharynx as related to the region of maximum medial movement of the pharyngeal musculature. What preventive measures can be taken to minimize the incidence of these problems following pharyngeal flap surgery?

Summary and Conclusions

This article describes and illustrates various patterns of velopharyngeal closure or attempted closure that were observed in the multi-view video-

fluoroscopic study of eighty-five nasal and non-nasal subjects, all without pharyngeal flaps, to emphasize the concept that the mechanism of velopharyngeal closure is sphincteric in nature. This mechanism results from the combination of velar and pharyngeal wall movements. Variations in the contribution of each of these components produce the several patterns of sphincteric closure or attempted closure of the velopharyngeal portal that were described.

A two-fold challenge was posed to professionals involved in the habilitation of patients with velopharyngeal incompetence and a number of questions were raised regarding the diagnosis and treatment of the patient with an incompetent velopharyngeal mechanism who may exhibit one of several sphincteric patterns of attempted closure of the velopharyngeal portal. In most instances no attempt was made to provide answers to the questions that were posed. This was deliberate as the answers are frequently less than optimally clear at this time. However, it is clear that multi-view video or cinefluorography offers an adequate approach for the examination of the sphincteric mechanism of velopharyngeal closure. It behooves us to begin taking the necessary steps required to incorporate this roentgen procedure into our clinical protocol if at all possible. Therefore, think sphincter!

Acknowledgments: The authors acknowledge the assistance of the Department of Instructional Communications, Upstate Medical Center, Syracuse, New York.

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