The Dynamics of Passavant's Ridge in Subjects With and Without Velopharyngeal Insufficiency— A Multi-View Videofluoroscopic Study

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Passavant's ridge was studied in 43 patients via *multiview videofluoroscopy* incorporating the simultaneous recording of speech. Ratings of the videotapes were made at full speed, in slow motion, and by stop-framing. The following results were found: (1) Just as there are variable patterns of velopharyngeal closure, there were also variations in the way in which Passavant's ridge is positioned relative to the velum, and in the ridge's subsequent role in velopharyngeal narrowing or closure. (2) The ridge was the primary pharyngeal structure at the level of the velum that closed or locally narrowed the velopharyngeal portal in 37% of patients. (3) Passavant's ridge usually appeared as a structure encompassing both the lateral and posterior pharyngeal walls, and its presence was usually associated with *active lateral pharyngeal wall motion.* (4) Passavant's ridge was more prominent when the head was in the hyper-extended rather than the neutral position. (5) Passavant's ridge moved in a highly consistent manner, synchronous with velar movement.

The functional significance of Passavant's ridge has been a source of controversy since Passavant (1863, 1869) first stated that the ridge is an essential component of the normal speech mechanism (Figure 1). Calnan (1954, 1957) disagreed with Passavant and stated that the ridge is a structure which is too low, too slow, too inconsistent, too prone to fatigue, and too uneconomical to contribute to velopharyngeal closure. More recently, Honjo et al. (1975), in a study of ten adult cleft palate patients, reported that the ridge has little importance in compensating for velopharyngeal insufficiency and thus should not be considered when planning pharyngoplasty.

In contrast, Carpenter (1966) and Carpenter and Morris (1968), in a study of the lateral cinefluoroscopic films of six subjects with repaired cleft palates, concluded that the ridge is a compensatory structure which appears with sufficient height, consistency and, coordination to contribute to velopharyngeal closure during speech. Investigations by Blair and Brown (1934), Barton (1955), Hagerty et al. (1958), Shelton et al. (1964), and Massengill et al. (1969) have also provided evidence suggesting that Passavant's ridge may contribute to velopharyngeal closure.

Thus, it is evident that disagreement still exists in regard to the appearance, movement, and functional significance of Passavant's ridge. The present study was designed to pro-

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vide a descriptive evaluation of the ridge during speech and to investigate: (1) the role of Passavant's ridge in velopharyngeal closure, (2) the positional relationship of the ridge to the velum, (3) the configuration and extent of lateral and posterior pharyngeal wall movement when a ridge is present, (4) the appearance of the ridge with the head in the hyperextended as opposed to the neutral position as seen on the lateral videofluoroscopic projection and, (5) the movement of Passavant's ridge as it relates to velar activity.

For the purposes of this study, Passavant's ridge was defined as a localized anterior projection from the posterior pharyngeal wall during speech as seen on the lateral videofluoroscopic projection.

Method

SUBJECTS. Videofluoroscopic studies of patients with Passavant's ridges were obtained from the clinical files of the University of Pittsburgh Cleft Palate Center; the Upstate Medical Center, Syracuse, New York; and the Montefiore Hospital and Medical Center, Bronx, New York. The subjects had been recorded over a seven-year period from January, 1969, to November, 1976.

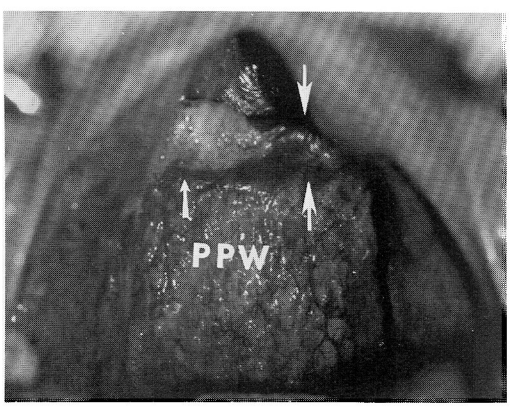

FIGURE 1. Intra-oral view of Passavant's ridge (arrows) in 27 year old male with repaired cleft palate. (PPW = posterior pharyngeal wall).

The videofluoroscopic studies of a total of 43 patients with Passavant's ridges were studied. The degree of velopharyngeal competency ranged from complete closure (in the non-nasal group) to a wide velopharyngeal gap (>6 mm). Twenty-nine of the subjects (Table 1) had hypernasal speech, including one non-cleft patient who had developed hypernasality following a tonsillectomy and adenoidectomy, one patient with a submucous cleft, and 27 patients with surgically repaired cleft palates. Fourteen patients with non-nasal speech were also evaluated. These included one patient with spastic dysphonia, ten with repaired cleft palates, and three normal volunteers. The subjects ranged in age from 3½ to 35 years with a mean age of 11.1 years and median and modal age of 10 years. Thirty subjects were male, and thirteen were female.

EXPERIMENTAL PROCEDURE. Passavant's ridge was observed via multi-view videofluoroscopy incorporating lateral, frontal, and base projections. Nine studies included the right and left oblique views as well, which provided the optimal visualization of the activity of the velum in relationship to that of the lateral pharyngeal walls. The videofluoroscopic procedure utilized in this study has been reported in detail elsewhere (Skolnick, 1970). The lateral view was observed both with and without the nasal instillation of a sterile solution of Barrosperse, a commercial colloidal barium preparation suspended in water and made to the consistency of heavy cream. All other views were performed with the barium mixture, which aided in the delineation of the margins of the velum and of the lateral pharyngeal walls.

There were some minor differences in the recording equipment used in the three centers. For example, the TV line rate at Montefiore was 945, while it was 525 at Pittsburgh and Upstate. However, these differences did not appreciably alter the quality of the recordings. Videofluoroscopic evaluations were re-

TABLE 1. Speech and diagnostic classification of the 43 subjects

non-nasal speakers	*n*	*nasal speakers*	*n*
Spastic dysphonia	1	Post T and A	1
Normal, volunteer	3	Submucous cleft	1
Repaired cleft palate	10	Repaired cleft palate	27
total	14	total	29

corded with simultaneous sound on three different one-inch video recorders (SONY EV 210 and EV 320; AMPEX 7500).

All studies were approximately two to three minutes in length. Subjects repeated a series of speech tasks designed to elicit speech in varying phonemic contexts. Even though the studies were performed in three separate institutions, the protocols were essentially identical and included the following tasks: isolated vowels, "mʌ-mʌ-mʌ" "pʌ-pʌ-pʌ," "kʌ-kʌ-kʌ," a sustained "s", an "s"-loaded sentence, a "k"-loaded sentence, and a sentence loaded with nasal consonants.

Video tapes of the multi-view videofluoroscopic evaluations were repeatedly viewed by the first author at full speed, in slow motion, and by stop framing. Rating scales were developed describing the structure and function of various aspects of the velopharyngeal valving mechanism. This was the procedure of choice since it was the purpose of this study to obtain a dynamic appreciation of Passavant's ridge.

Inter-judge reliability established between two independent raters, (E.G. and B.J.M.) both experienced with the multi-view procedure, was 90 per cent over 5 per cent of the sample. The primary rater's intra-reliability was also established over 5 per cent of the sample and was 91 per cent.

Results and Discussion

POSITION OF PASSAVANT'S RIDGE. Passavant's ridge was first observed in lateral projection with the head in the upright posture. The ridge's position was considered in relationship to the positions of the velar eminence, the vertical length of the velum, the uvula, the adenoids and the posterior pharyngeal wall. While previous studies have described the level of the ridge in relationship to the tubercle of the atlas (Harrington, 1944; Calnan, 1957; Carpenter, 1966), it was felt that it would be of greater clinical relevance to describe the ridge as it related to the structures comprising the velopharyngeal valving mechanism.

The positional relationship of Passavant's ridge to the velum during velopharyngeal narrowing or closure remained essentially constant within each individual. However, there were several types of velar-pharyngeal-ridge patterns observed within the group of 43 subjects (Figure 2). When rating the ridge in regard to the velum, 4.7 per cent were opposite the velar eminence, 58.1 per cent were opposite the vertical portion of the velum, 25.6 per cent were directly opposite the uvula and 11.6 per cent were situated below the uvula. Therefore, 88 per cent of the ridges were positioned with sufficient height on the posterior pharyngeal wall to contact the velum if and when velopharyngeal closure occurred.

The position of Passavant's ridge was also evaluated to determine if it might serve as a primary, secondary, or insignificant site of narrowing or closure. These patterns are summarized in Table 2. Typical patterns are illustrated in Figures 3, 4, 5, and 6. However, it should be noted that there is some variation between patients in regard to the orientation and size of the ridge as well as in the extent of velopharyngeal closure. Passavant's ridge was considered to be a primary site of closure or narrowing if it was the highest structure projecting from the pharyngeal wall which served either to narrow or to eliminate the velopharyngeal gap at the level of the velum. The ridge was defined as having a secondary role if it was a lower, second point of narrowing or contact.

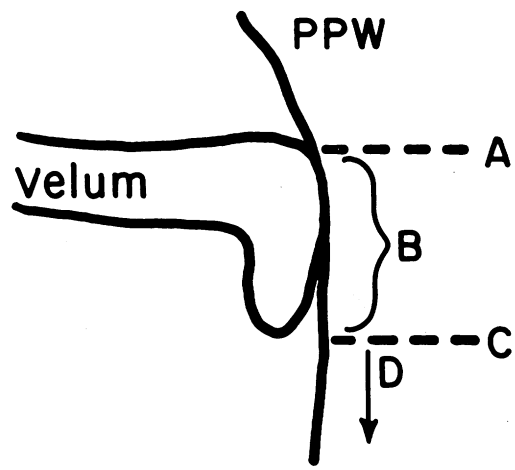

FIGURE 2. Postition of Passavant's ridge relative to velum (N=43). A-Opposite velar eminence: 4.7%; N=2. B-Opposite vertical length of velum: 58.1%; N=25. C-Opposite uvula: 25.6%; N=11. D-Below uvula: 11.6%, N=5. (PPW=posterior pharyngeal wall).

TABLE 2. Summary of velar-pharyngeal-ridge patterns of velopharyngeal narrowing or closure

role of Passavant's Ridge	*total n (43)*	*% of total n*	*non-nasal n (14)*	*%*	*hypernasal n (29)*	*%*
Primary source of narrowing or closure	16	37.2	3	21.4 (7.0% of 43)	13	44.8 (30.2% of 43)
Secondary, lower point of narrowing or closure	10	23.3	5	35.7 (11.6% of 43)	5	17.2 (11.6% of 43)
Increases the extent of the portion of PPW* approximating or contacting the velum	12	27.9	4	28.6 (9.3% of 43)	8	27.6 (18.6% of 43)
Is below the uvula; does not contribute to velar-PPW narrowing or approximation	5	11.6	2	14.3 (4.7% of 43)	3	10.3 (7.0% of 43)
Totals	43	100.0	14	100.0	29	99.9

* posterior pharyngeal wall.

Passavant's ridge was a primary structure in either narrowing or eliminating the velopharyngeal gap in 37.2 per cent of the subjects (Figure 3). In 6.9 per cent, Passavant's ridge was a primary source of successful velopharyngeal closure. In one instance, this occurred in a volunteer, noncleft subject who appeared to have an anatomically normal velopharyngeal mechanism. However, it is not known if closure would have occurred had the ridge not been present in these cases. The necessity of the ridge to closure is particularly questioned in those subjects in whom the ridge was flattened by vigorous, well-coordinated velar activity.

The ridge increased the vertical extent of the portion of the posterior pharyngeal wall approximating or contacting the velum in 27.9 per cent of the cases (Figure 4). In 23.3 per cent, the ridge contacted or approximated the velum, but the velum also contacted the adenoid pad or posterior pharyngeal wall above the ridge so that the ridge was a separate, lower point of narrowing or closure (Figure 5). The contribution of Passavant's ridge to the reduction of hypernasality is not entirely clear in these two instances. Because velopharyngeal closure is defined as the existence of a complete seal between oral and nasal cavities, some would say that the vertical extent of closure is not an important element in the existence of a complete seal. We suspect, however, that the vertical extent of closure may be important in the velopharyngeal mechanism with borderline competency, as it is conceivable that an increased area of contact, or a second point of contact, may assist the individual in maintaining closure.

As already mentioned, the ridge was located below the uvula in 11.6 per cent of the cases (Figure 6) and thus did not narrow the space between the posterior pharyngeal wall and the velum. These results disagree with the traditional assumption that Passavant's ridge is usually too low to assist in velopharyngeal closure (Calnan, 1957). Also, it seems possible that the Passavant's ridge which appears below the level of the uvula may still assist in the reduction of hypernasality by serving as a partial barrier to airflow during speech, particularly if the ridge is a large one in relationship to the velopharyngeal gap (Figure 7). It is thus recommended that the significance of each ridge be evaluated on an individual basis prior to injecting teflon, constructing a speech appliance, or performing a pharyngoplasty.

RIDGE POSITION AND SPEECH. The proportion of hypernasal subjects with Passavant's ridge as a primary source of narrowing or closure was significantly higher than the proportion of non-nasal subjects with this pattern. (two-tailed z test, $p < .01$) However, there were no significant differences in the proportion of hypernasal versus non-nasal speakers in which Passavant's ridge either increased the vertical extent of the portion of the posterior pharyngeal wall approximating or contacting the velum, was a second, lower point of narrowing or closure, or was located below the uvula.

LATERAL PHARYNGEAL WALL MOTION. Pas-

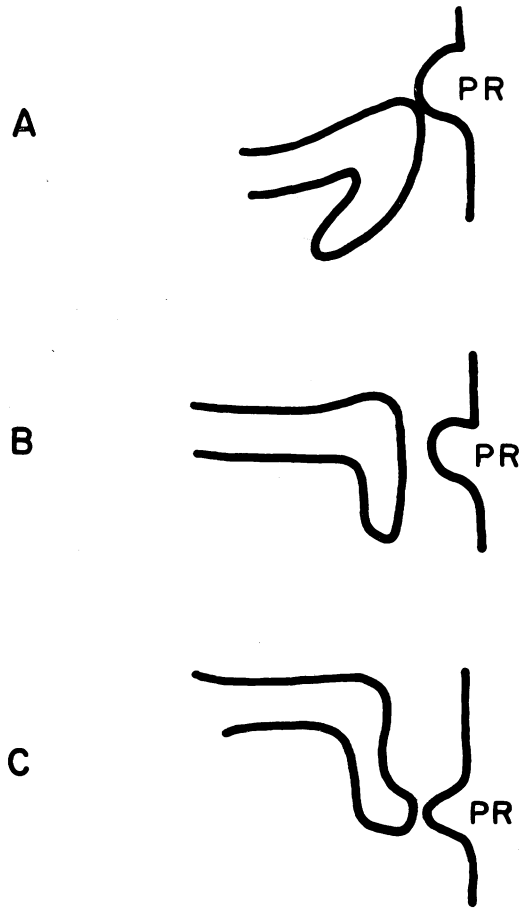

FIGURE 3. Passavant's ridge as a primary source of velopharyngeal narrowing or closure (37.2% of the 43 subjects). Pattern A: velar eminence to Passavant's ridge (1 non-nasal subject, 1 hypernasal subject). Pattern B: vertical portion of velum to Passavant's ridge (2 non-nasal subjects, 7 hypernasal subjects). Pattern C: uvula to Passavant's ridge (0 non-nasal subjects, 5 hypernasal subjects).

savant's ridge, as seen on the lateral view, was usually associated with active lateral pharyngeal wall motion as seen on the frontal videofluoroscopic projection. In 75.5 per cent of the 40 cases with technically adequate frontal views, maximum lateral pharyngeal wall movement during speech was characterized by localized movement of the walls at least 75 per cent of the distance from their position at rest to the midline (Figure 8). The maximum lateral pharyngeal wall motion ranged from 20 per cent to 100 per cent of the distance to the midline with all subjects showing some degree of lateral wall motion. This localized motion had a shelf-like configuration, the occurrence of which was significant at the .001 level of confidence using the two-tailed z test (Siegal 1959).

The frequent occurrence of active lateral

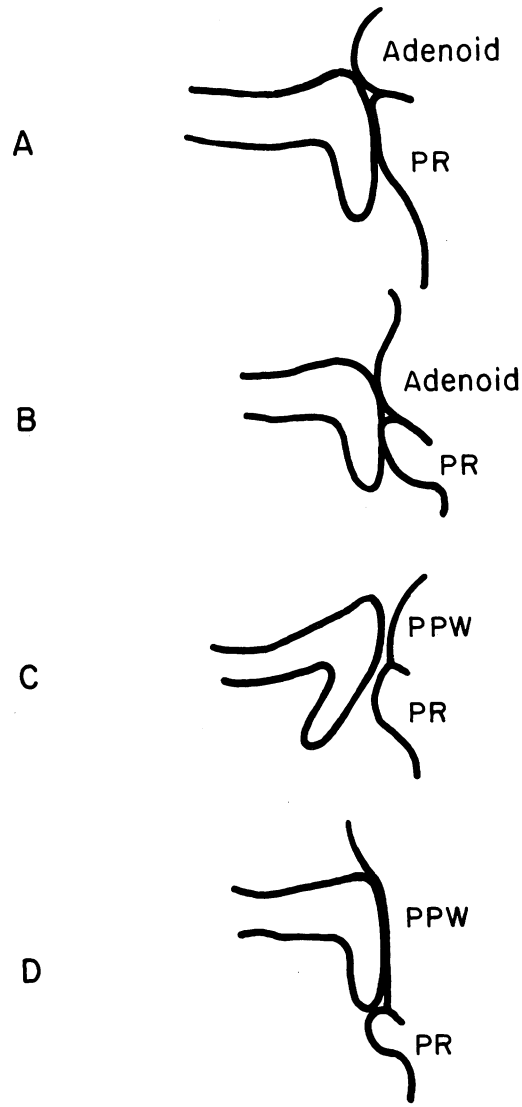

FIGURE 4. Passavant's ridge increasing the extent of the portion of the posterior pharyngeal wall approximating or contacting the velum (27.9% of the 43 subjects). Pattern A: velar eminence to adenoid; Passavant's ridge to vertical portion of velum (1 non-nasal subject, 2 hypernasal subjects). Pattern B: vertical portion of velum to adenoid; Passavant's ridge to vertical portion of velum (1 non-nasal subject, 1 hypernasal subject). Pattern C: vertical portion of velum to posterior pharyngeal wall; Passavant's ridge to vertical portion of velum (1 non-nasal subject, 4 hypernasal subjects). Pattern D: velar eminence to posterior pharyngeal wall; Passavant's ridge to uvula (1 non-nasal subject, 1 hypernasal subject).

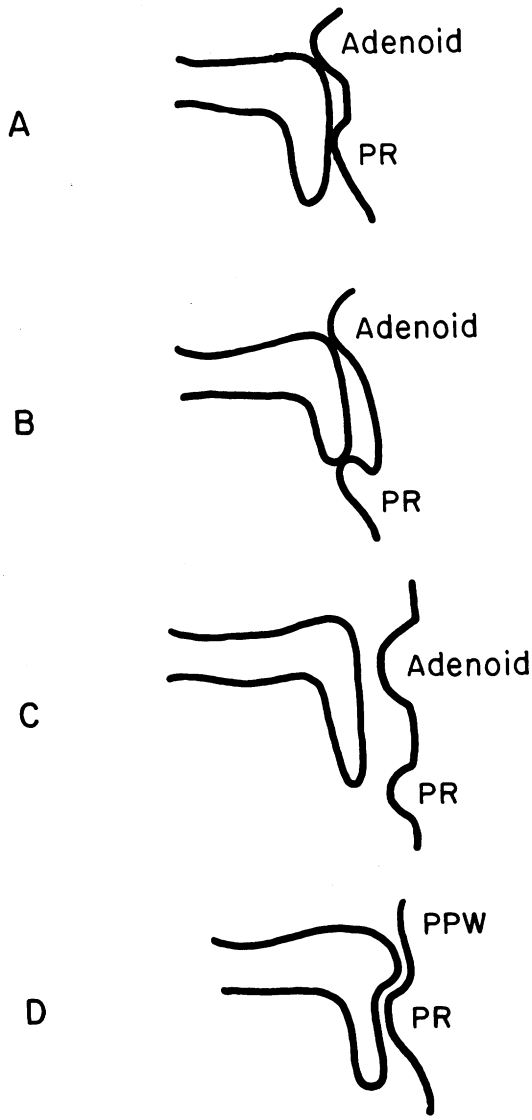

FIGURE 5. Passavant's ridge as a second, lower point of closure or narrowing (23.3% of the 43 subjects). Pattern A: eminence of velum to adenoids; Passavant's ridge to vertical portion of velum (3 non-nasal subjects, 1 hypernasal subject). Pattern B: velar eminence to adenoid; Passavant's ridge to uvula (1 non-nasal subject, 2 hypernasal subjects). Pattern C: vertical portion of velum to adenoid; Passavant's ridge to uvula (1 non-nasal subject, 1 hypernasal subject). Pattern D: vertical portion of velum to posterior pharyngeal wall; Passavant's ridge to vertical portion of velum (0 non-nasal subjects, 1 hypernasal subject).

pharyngeal wall motion as seen on frontal projection was confirmed by the previously described patterns of sphincteric activity (Skolnick et al., 1973; Skolnick, 1975; Skolnick et al., 1975), seen on the base view (Figure 9). 78.1 per cent of the 32 cases with technically adequate base projections demonstrated a circular pattern of narrowing or closure, indicating essentially equal contributions to closure of the posterior pharyngeal wall, lateral pharyngeal walls, and velum. Passavant's ridge was observed to be a distinct, crescent-shaped, medial ridge continuing along the lateral pharyngeal walls in 36.0 per cent of those cases with circular closure. In the other 64 per cent, the ridges tended to be less prominent, and, though distinct on the lateral and frontal views, were not seen on the base views. We suspect that these smaller Passavant ridges were more difficult to visualize on the base view because the resolution and magnification of the base images were often not comparable to those of lateral and frontal images. This crescent-shaped ridge

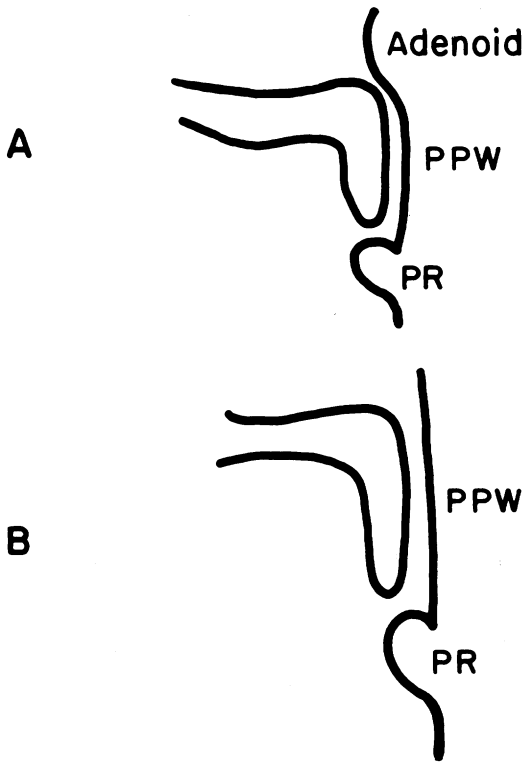

FIGURE 6. Passavant's ridge situated below the uvula (11.6% of 43 subjects). Pattern A: eminence to adenoid; Passavant's ridge below uvula (1 non-nasal subject, 3 hypernasal subjects). Pattern B: vertical portion of velum to posterior pharyngeal wall; Passavant's ridge below uvula (0 non-nasal subjects, 1 hypernasal subject).

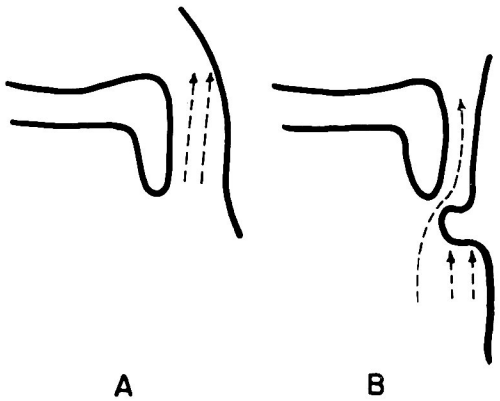

FIGURE 7. Hypothetical role of Passavant's ridge when located below the uvula. A. No Passavant's ridge; air flow has no barrier. B. Passavant's ridge which could reduce hypernasality.

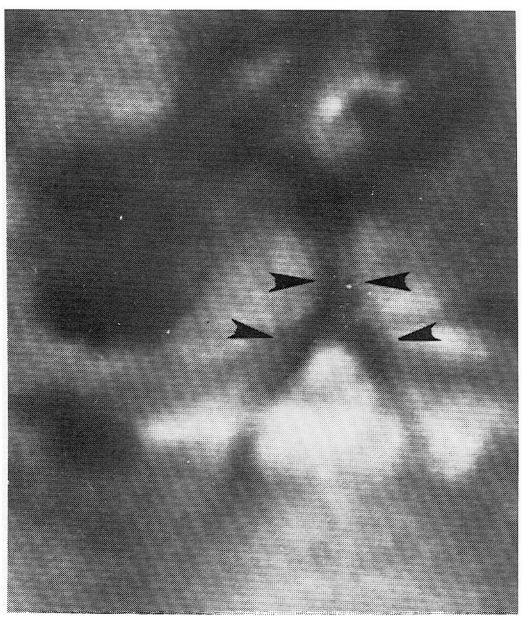

FIGURE 8. Localized medial movement of lateral nasopharyngeal walls (arrowheads) which almost meet in midline during sustained /s/ in 11 year old hypernasal male with repaired cleft palate.

was generally associated with a very prominent Passavant's ridge as seen on the lateral projection. 15.6 per cent of the subject group had coronal narrowing or closure patterns, meaning that the velum and posterior pharyngeal wall, (i.e. Passavant's ridge) were the predominant sites of activity. 3.0 per cent had oval patterns so that, although there was substantial movement of the velum and posterior pharyngeal walls, this movement was exceeded by the lateral pharyngeal wall movement toward the midline. Finally, 3.1 per cent had sagittal patterns of closure in which the lateral pharyngeal wall motion was clearly the predominant component to the narrowing. Chi square (Siegal, 1959) was significant at the .001 level, ($\chi^2 = 49.5$, df = 3, N = 32), reflecting the preponderance of circular closure. The high percentage of circular closure is interesting in light of a study of non-Passavant ridge cases in which only 10 per cent of 80 non-nasal, anatomically normal cases and 20 per cent of 500 hypernasal cases had circular closure (Croft and Shprintzen, 1977).

Our observations suggest that Passavant's ridge usually appears as a structure which encompasses both the lateral and posterior pharyngeal walls and can not be considered as only a midline structure. Therefore, the presence of a midline bulge, as seen on lateral x-rays, almost always coincides with localized regions of medial movement of the lateral pharyngeal walls in the nasopharynx.

NEUTRAL VERSUS EXTENDED HEAD POSITION. The prominence of Passavant's ridge

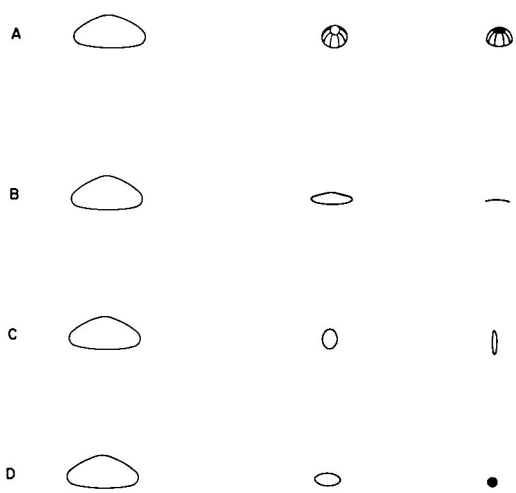

FIGURE 9. Patterns of narrowing or closure in patients with Passavant's ridges as seen on base projection, (N = 32). Left hand column represents portal at rest, middle column during partial closure, and right hand column at maximum closure. A. Circular pattern: 78.1% (Note: crescent shaped ridge which was seen in 36.0% of the patients with the circular pattern.) B. Coronal pattern: 15.5%. C. Sagittal pattern: 3.1%. D. Oval pattern: 3.0%.

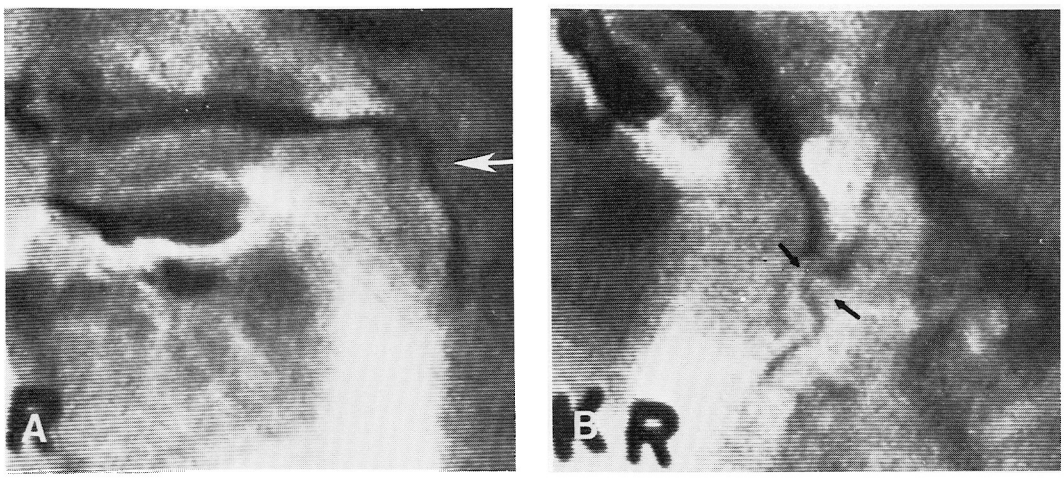

FIGURE 10. Passavant's ridge (arrow) in lateral view: A) Neutral versus B) hyper-extended head position during phonation of sustained /s/. Note the increased prominence of the ridge in hyperextension.

was studied in 14 patients who were laterally fluoroscoped in both the neutral and hyper-extended head positions. Passavant's ridge became most prominent (Figure 10) when the head was hyper-extended (Sign test, two-tailed, $p = .008$). These data are supported by our clinical experiences, as we have recently become aware of extremely minute Passavant's ridges in the neutral position only after their initial detection in the hyper-extended position.

The question of the mechanism or mechanisms responsible for the formation of Passavant's ridge is not yet resolved. It seems to us that any process which increases the tension placed upon the muscle or muscles comprising Passavant's ridge may cause the ridge to appear. There may be anatomic variability in the discreteness and/or strength of the fiber attachments of the ridge musculature in the lateral and posterior pharyngeal walls. In individuals with ridges, these fibers may form more discrete bundles that are interwined to a lesser extent with the adjacent muscular and faucial planes than in individuals without ridges.

This effect can be seen clinically in two ways. First, subsequent to the deepening of the pharynx, we have seen an increase in ridge prominence or have detected a ridge where none had existed before. This is not surprising since McWilliams et al. (1968) reported increased evidence of velopharyngeal incompetence when the head position was shifted from neutral to hyperextension. A ridge may also appear for the first time following maxillary advancement.[1] In such cases, the distance between the attachments of the fibers of the Palatopharyngeus m. and/or the fibers of the Superior Constrictor m., which attach to the palatal aponeurosis and to the medial pyerygoid plate respectively, would increase, possibly resulting in the observed ridge prominence. Second, a Passavant's ridge might result when an increased demand is placed on the velopharyngeal musculature, as seen when the ridge apparently appears as a compensatory mechanism in patients with velopharyngeal incompetence.

RIDGE MOVEMENT WITH SPEECH. Passavant's ridge moved in a highly consistent manner. In all 43 cases, the appearance and disappearance of the ridge was judged to be in synchrony with that of velar behavior. The prominence of the ridge appeared to be related to the degree of velar elevation and was greater for non-nasal consonants than for nasal consonants. The ridge maintained a relatively stable position during rapid, connected speech except when interrupted by nasal consonants.

A few comments are necessary to explain

[1] These patients with Passavant's ridges noted only following maxillary advancement were evaluated after this study was completed.

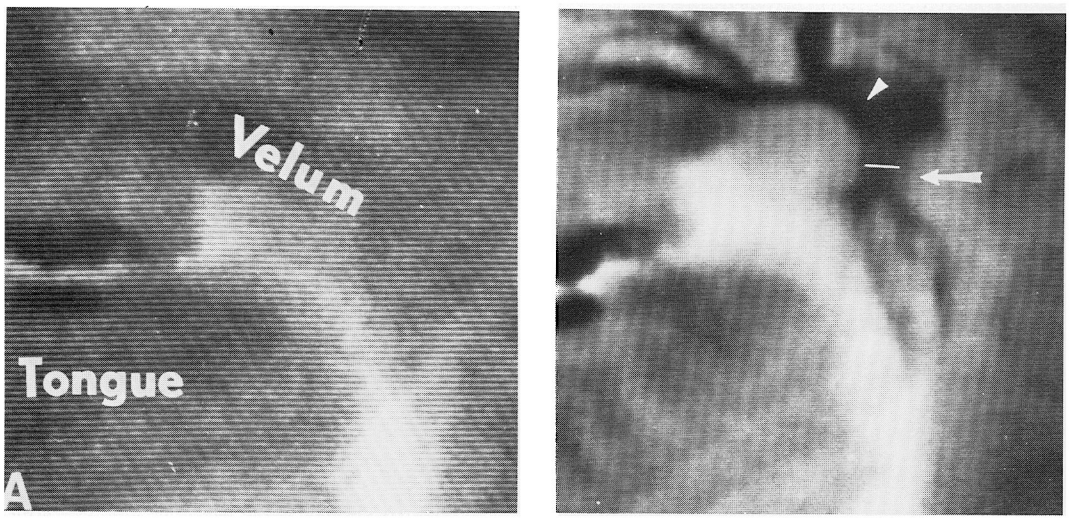

FIGURE 11. Comparison of clarity of structures as seen on lateral view with and without the barium coating of the nasopharynx. The patient is an 11 year old hypernasal male with repaired cleft palate. A) sustained /s/; no barium. B) sustained /s/; barium. Note: well defined Passavant's ridge (arrow), posterior velar surface (arrowhead), and width of velopharyngeal gap (—) on film with barium in nasopharynx.

why these results differ from some previous investigations in regard to the relationship of Passavant's ridge to speech tasks. First, many studies have been performed without a barium coating of the pharyngeal area. We have found that the use of barium is essential for the subtle observation of the ridge during speech (Figure 11). Second, in studies performed without the simultaneous recording of speech, the ridge might well appear to move in a sporadic, inconsistent way when, instead, it is reflecting the complexity of phonemic coarticulation. When the ridge's movements are viewed in conjunction with the speech signal, they appear to be highly predictable and consistent. Finally, the effect of articulatory competency on the ridge is usually not mentioned. A failure to consider this may result in the erroneous description of inconsistent, random ridge movement. For example, when one subject in this study produced an /s/ with a severe lateral distortion, the palate, lateral pharyngeal walls, and posterior pharyngeal wall consistently demonstrated a complete absence of movement, although there was active movement with correctly articulated phonemes. In this instance, the ridge was reacting in a superbly consistent manner in its reflection of the underlying articulation problems.

In summary: (1) These data suggest that just as there are variable patterns of velopharyngeal closure (Skolnick et al., 1975), there are also variations in the way in which Passavant's ridge is positioned relative to the velum and in the ridge's subsequent role in velopharyngeal narrowing or closure. (2) The ridge was the primary pharyngeal structure at the level of the velum that closed or locally narrowed the velopharyngeal portal in 37% of patients. (3) Passavant's ridge was usually associated with active lateral pharyngeal wall motion. (4) Passavant's ridge was more prominent when the head was in the hyper-extended rather than the neutral position. (5) Passavant's ridge moved in a highly consistent manner, synchronous with velar movement.

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