Study of the Normal and Insufficient Velopharyngeal Valve by the "Forced Sucking Test"

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A thorough assessment of the velopharyngeal (VP) closure dynamics is important for therapeutic planning in patients with nasal speech. An additional diagnostic tool to the standard endoscopic examination of the VP valve, the "Forced Sucking Test" (FST) is presented. In this study, 110 patients with a normal VP valve and 40 patients with VP insufficiency were subjected to a comprehensive endoscopic examination. When existent, Passavant's ridge clearly appears in 80% of these cases during the FST. This is advantageous, since the ridge is often unseen during routine nasendoscopy. Passavant's ridge appears indistinguishable in shape and level during speech and FST. During FST, the bulge of the uvular ridge is clearly seen on the flat or concave nasal surface of the velum. In cases of diastasis of the velar musculature, the midline V-defect of the velum is clearly seen. The test is particularly important in children with concomitant adenoid hypertrophy. The findings are discussed in terms of their implications for the anatomy and physiology of the VP valve. FST is recommended as an additional and complementary part of the endoscopic examination of the VP valve.

INTRODUCTION

A thorough assessment of the velopharyngeal (VP) valve closure dynamics is important for therapeutic planning in patients with nasal speech. Nasendoscopy is the most important method for the examination of the VP valve. The nasendoscopic view of the three-dimensional VP sphincter is limited during its closure and observation of its entire complex is impossible. A marked individual variability exists in the closure mechanism of the VP valve. Therefore, it is essential to define the relative contribution of the velum, lateral, and posterior pharyngeal walls to its closure, thus determining the individual closure patterns.[1,2]

Passavant's ridge is the localized anterior bulging of the posterior pharyngeal wall. Passavant's ridge can be seen at nasendoscopy and on the lateral radiograph of the neck. There are many variations in the position of PR relative to the velum. It may be formed at the level of the velar eminence, the uvula, or below the uvula.[3] Since Passavant's ridge can be formed under the plane where the velum contacts the posterior pharyngeal wall, it is often veiled during nasendoscopy.[4]

To solve this problem, Karnell, *et al.*[4] suggested routine use of tandem oral and nasal endoscopy. In practice, because of the patient's discomfort during oral endoscopy and because of the interference with speech and nonspeech activities, performing oral endoscopy of the VP valve is not always possible, and the results are often inconclusive. In the occult submucous cleft palate, hypoplasia of the muscularis uvulae and diastasis of the velar musculature can be endoscopically observed.[5] The different degree of malformations of the VP valve are not always easy to determine and the muscularis uvulae can be flat or totally absent.[6,7]

In a previous study, it was reported that Passavant's ridge clearly appears during forced continuous suction, and the uvular ridge is seen on the flat or concave velum.[8,9] During the act of suction, the dorsum of the tongue rises while the velum descends; thus, the forced contact between these two structures forms the tongue-palatal valve which disconnects the oral cavity from the oropharynx behind it.[10] The VP valve remains open, permitting full observation during nasendoscopy of the entire VP isthmus including the nasal surface of the velum, and the posterior and lateral pharyngeal walls. Prior to recommending the routine use of FST as a complementary part of routine nasendoscopy of the VP valve, it was necessary to

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TABLE I.
Patient's Profile and Velopharyngeal Closure Patterns.

	No. of Pts.	Age/Range Mean	Sex F/M	Coronal	Circular	Circular with Passavant's Ridge	Radiological Examination
Unoperated occult submucous	15	4.5 to 24 / 10	10/5	11	2	2	9
Unoperated submucous	5	5 to 21 / 7.5	3/3	3	1	1	2
Primary repaired clefts	14	5 to 38 / 15	9/5	9	3	2	3
Pharyngeal flap	5	5.5 to 44 / 16	4/1	4		1	2
Carcinoma of soft palate	1	43	1/0			Coronal + Passavant's ridge	1
Total	40	4.5 to 44 / 11	27/13 / 12	27	6	7	17

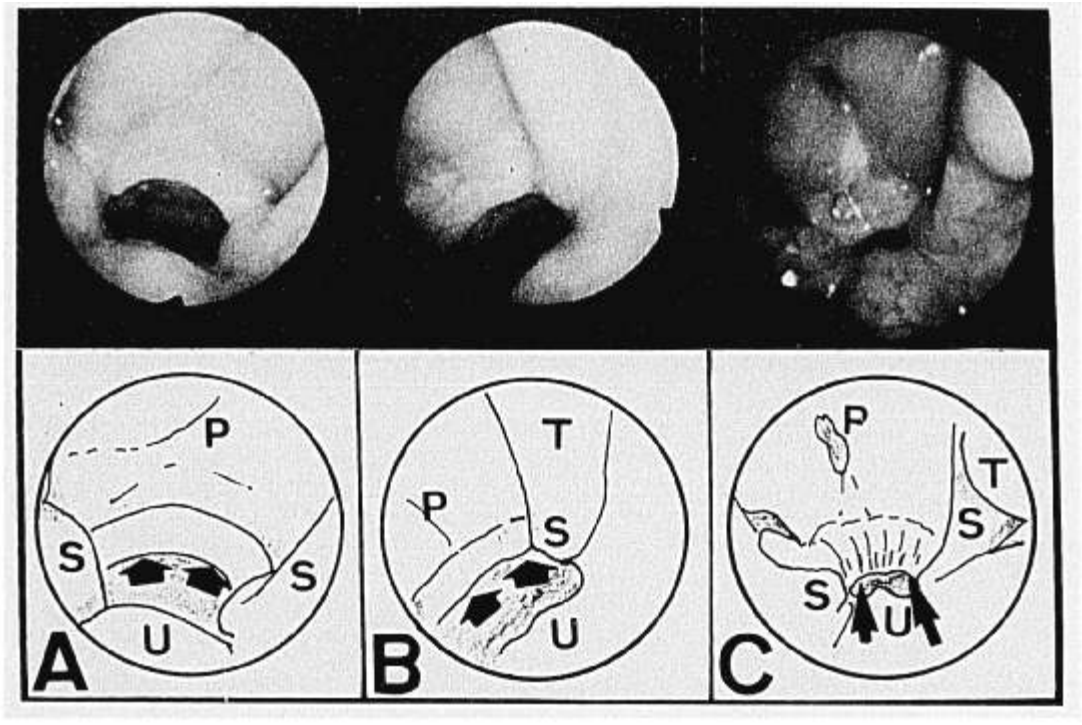

Fig. 1. The endoscopic appearance of Passavant's ridge (arrows) during the Forced Sucking Test (FST) (**A, B**) and in speech (**C**). P = posterior pharyngeal wall; S = salpingopharyngeal fold; T = torus; U = velum.

establish the value of this test in the diagnosis of the pathology underlying the incompetent VP valve.

In the present study the following questions were addressed:

1. Is Passavant's ridge, which appears during FST, equal in shape and location to that in speech?

2. Can Passavant's ridge appear in FST in patients with no ridge in speech? Does the ridge appear in speech and not in FST?

3. Can the observation of Passavant's ridge and its relation to the lateral pharyngeal walls add information about the mechanisms involved in its formation?

4. What additional information can be obtained by the application of FST in the endoscopic examination of the insufficient VP valve?

PATIENTS AND METHODS

Group A: Individuals With Normal VP Valve

One hundred ten normally speaking individuals were included in the study. These patients had no personal or family history of cleft lip or palate, and no oral, maxillary, or pharyngeal surgery. Sixty-three were women and 47 were men, ranging in age from 25 to 55 with a mean of 39 years.

Group B: Patients With VP Insufficiency

Forty patients referred with suspected VP insufficiency were included in the study. Patients' profiles and pathology are presented in Table I. One of the patients underwent prior surgery for carcinoma of the soft palate 3 years earlier. The speech rating scale proposed by Philips[11] was used. A

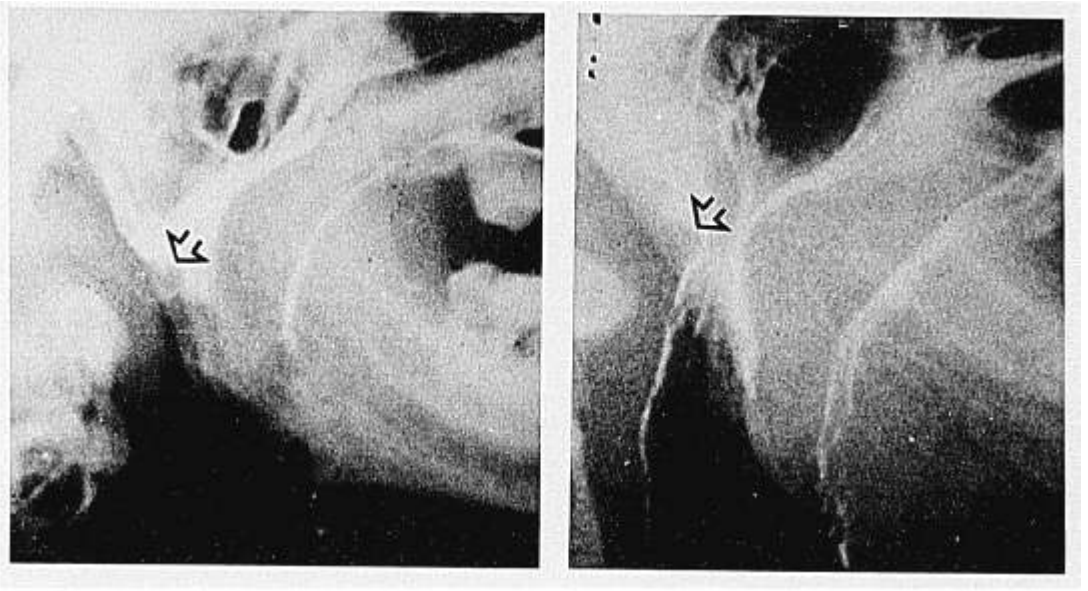

Fig. 2. Lateral radiographic view of the velopharyngeal valve during FST. Note the typical forward bulging of the velum forcefully attached to the raised base of the tongue. Passavant's ridge on the posterior pharyngeal wall is indicated by the arrows.

score of 1 to 2 was defined as mild, 3 to 4 as moderate, and 5 or higher as severe VP insufficiency.

Experimental Procedure

All patients had a nasendoscopic examination of the VP valve as described elsewhere.[2,12,13] The endoscopic examination was performed with a flexible nasopharyngoscope Olympus ENF-2P. Using the classification described by Skolnick, *et al.*[1] and Croft, *et al.*,[2] the patterns of VP valving were categorized as follows:

1. Coronal: The major component of the VP valving is the velum. The lateral pharyngeal walls move medially to approximate the lateral edges of the velum.

2. Sagittal: The major component of the VP valving is the lateral pharyngeal walls. The velum moves posteriorly only slightly, approximating the anterior edge of the abutted lateral walls.

3. Circular: The velum and the lateral pharyngeal walls move equally, closing the VP port at the midline.

4. Circular with Passavant's ridge: As in the circular pattern, there is equal contribution to closure of the velum and lateral walls, but there is also anterior movement of the posterior pharyngeal wall resulting in a truly sphincteric closure pattern.

The FST was performed by instructing the patient to powerfully suck on an obstructed catheter for 5 seconds. The movement and shape of the VP walls were then observed with special attention to the velum and posterior pharyngeal wall.

Fluoroscopic examination of the VP valve with barium was performed on 13 randomly selected normal individuals and on 17 of the patients with a pathologic VP valve. The radiographic examination was performed by a 100-mm TV camera (Siemens, Sircain 103. Monitor Siemens 1764C) with a maximum rate of three exposures per second. Coating of the pharyngeal walls, velum, and tongue with a suspension of barium sulphate was performed as described by Skolnick.[14] Lateral and frontal views were obtained at rest, on /*ah*/, /*s*/, and FST.

The configuration of the velum and posterior pharyngeal wall was obtained in lateral projection. The level and shape of Passavant's ridge were noted relative to the tubercle of the atlas. The positional relationship of the ridge opposite the level of the velar eminence, the vertical length of the uvula, or below the uvula[3] were noted during speech.

RESULTS

Group A: Individuals With Normal VP Valve

Endoscopic study. The patients were classified according to their VP closure patterns as follows: coronal in 60, sagittal in 1, circular in 26, and circular with Passavant's ridge in 23 patients. In all 23 patients exhibiting circular with Passavant's ridge, the ridge appeared in continuous speech and during enunciation of /*s*/, but in 4, the ridge did not appear during enunciation of /*ah*/.

During the FST, the VP valve remained open, permitting observation of the pharyngeal walls. The velum descends anteriorly, and the bulge of the uvular ridge on the nasal surface of the velum was clearly seen (Fig. 1-A). During FST, some medial movement of the entire lateral pharyngeal walls was observed in 33% (20 of 60) of the coronal, in 100% (1 of 1) of the sagittal, in 58% (15 of 26) of the circular type, and in 65% (15 of 23) of the circular with Passavant's ridge. In 80% (18 of 23) of the patients with Passavant's ridge in speech, the view was not veiled by the velum and lateral pharyngeal walls, thus allowing clear visualization of the Passavant's ridge during FST.

The ridge appeared persistently or alternatively during the maximal effort of sucking. In 14 of the patients with Passavant's ridge, it appeared on the posterior pharyngeal wall (Fig. 1-A) and on the posterolateral angles, disappearing posteriorly to the salpingopharyngeal wall (Fig. 1-B). In the other 4 patients, the ridge was associated with marked medial movement of the lateral pharyngeal walls toward

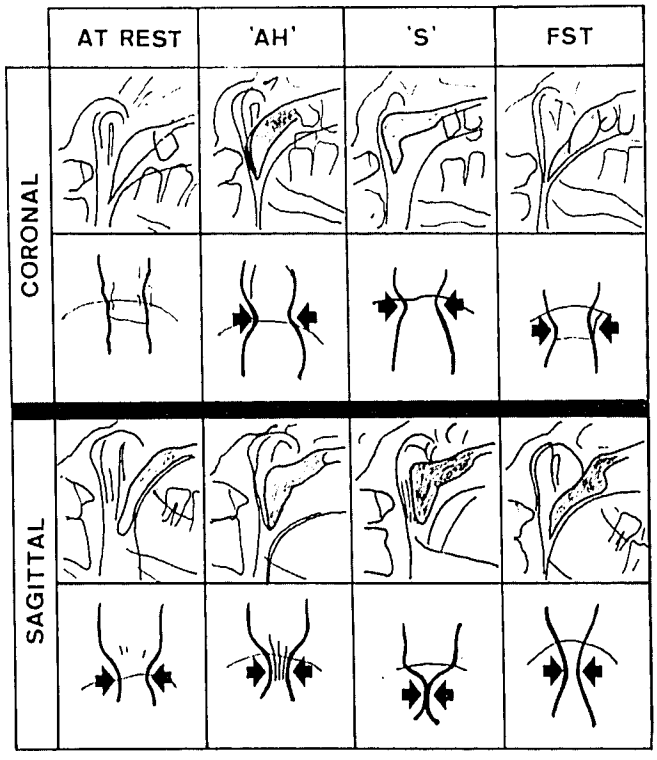

Fig. 3. Lateral and frontal radiographic view ot coronal type velopharyngeal valve (**top**), and sagittal type (**bottom**). The activities performed are noted on the horizontal axis. In the frontal view the medial movement of the lateral pharyngeal walls are indicated by the arrows. The dorsum of the tongue is indicated by the horizontal traces.

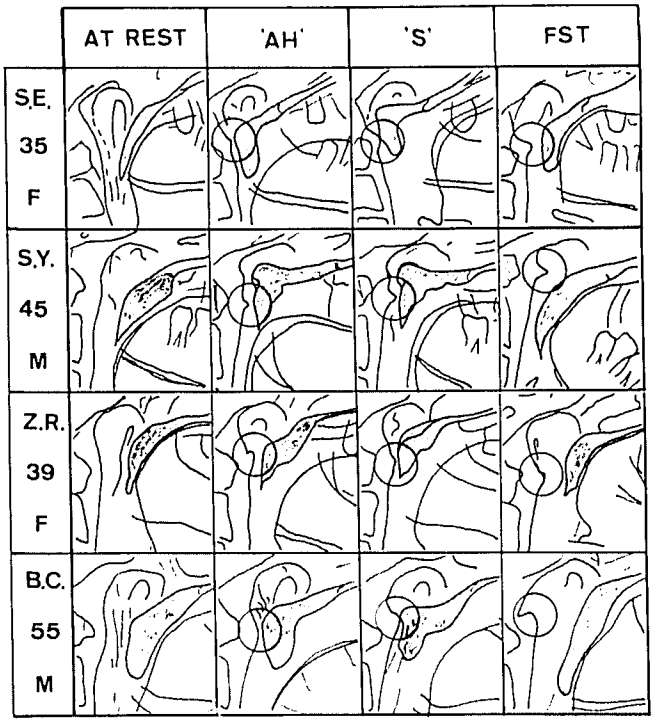

Fig. 4. Lateral radiographic view of Passavant's ridge in phonetic activity and FST in four patients. Patients' ages, in years, and sex are shown on the vertical axis.

the velum. In all cases, the Passavant's ridge maintained the same configuration and level as in speech. During speech, the ridge, the lateral pharyngeal walls, and the velum close in a circular pattern. In 7 cases, the ridge was initially discovered during the FST, and only at repeated examination was it found during speech. In patients with no Passavant's ridge in speech, Passavant's ridge in FST was not observed.

Radiologic study. Thirteen patients had a radiological study: 6 were coronal, 1 sagittal, 1 circular, and 5 circular with Passavant's ridge. In all patients, on lateral projection during FST, forward bulging of the velum forcefully attached to the raised base of the tongue was observed (Fig. 2), forming the tongue-palatal valve.[7] No anterior movement of the posterior pharyngeal wall was found during production of */ah/*, */s/* and during FST in patients endoscopically found to have closure patterns with no Passavant's ridge (Fig. 3).

In five patients with Passavant's ridge, its shape and level relative to the tubercle of the atlas were constant during speech and FST (Fig. 4). In these five patients, the ridge also continued to be present during the oral and pharyngeal phases of deglutition (Fig. 5).

On frontal projection during phonetic activity, a selective medial movement of the lateral pharyngeal walls appeared (Fig. 6). During FST, medial movement of a large part, or even the entire lateral pharyngeal walls, was found in all these patients. This movement was quantitatively, but not qualitatively, different from the movement in patients with other closure patterns. In two of these patients, the medial movement of the lateral pharyngeal walls was not observed endoscopically.

Group B: Patients With Velopharyngeal Insufficiency

The patients were classified according to their hypernasality as follows: mild (17), moderate (15), and severe (8). Patients' categorization according to their VP malformations and closure patterns is depicted in Table I.

Velar configuration. In all patients, no bulging of the uvular ridge was seen at rest or in phonation. Some convexity on the midline of the velum was seen in a 7-year-old girl (Fig. 7-A,B) and in another 5-year-old girl, both with an occult submucous cleft palate with severe hypernasality. During connected speech and */ah/*, no movement of the velum was found, while during */s/*, mild elevation of the velum was observed. During the FST, a deep V-shaped defect clearly formed in the midline (Fig. 7-C). Similarly, in a 21-year-old patient with submucous cleft palate, a whitish flat convexity was found on the midline. In FST, a large V-shaped defect was found, most commonly in the zona pellucida, which was observed intraorally.

During the FST, the velum was invaginated ante-

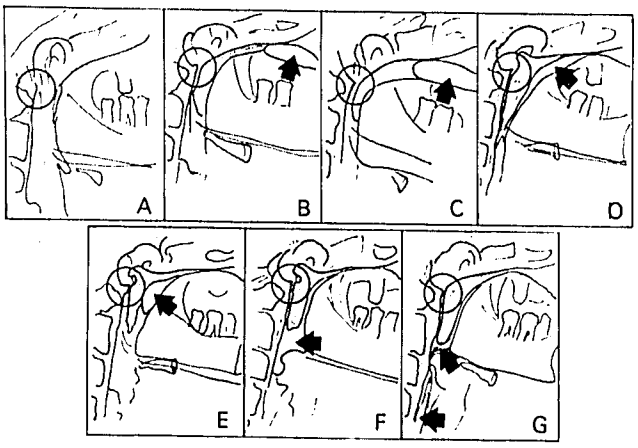

Fig. 5. Lateral radiographic view of the velopharyngeal valve at rest (A); during forced sucking forming Passavant's ridge (B, C); during oral and pharyngeal phases of swallowing (D through G). Arrows indicate bolus. The Passavant's ridge is indicated by circles.

riorly showing convexity in four patients with occult submucous cleft palate, in eight with primary repaired clefts, and in two with pharyngeal flaps. A deep midline V-shaped defect during the FST was found in all other patients. One patient who underwent excision of carcinoma of her left soft palate, showed a small uvular ridge during the test.

Hypertrophic adenoids occluded most of the nasal choanae in two patients (a 4½-year-old girl, a 5-year-old boy), both with occult submucous cleft palate, and in one patient (a 9-year-old girl) with a submucous cleft palate; all had moderate hypernasality. They had veloadenoidal closure and it was impossible to observe the velum during valving. Their diagnosis was made during the FST because the velum descended anteriorly, showing the characteristic midline V-shaped defect. In cases with pharyngeal flaps, the flap was clearly observed.

The radiological examination showed a characteristic thinning of the velum on lateral projection in seven cases with occult submucous cleft palate (Fig. 8), in two cases with primary repaired cleft palate, and in one case with a pharyngeal flap (Fig. 9, left). In a patient with submucous cleft palate, the velum during FST was shortened and concave (Fig. 8, bottom). In one patient with a pharyngeal flap, during the radiological examination during vigorous sucking, the velum acquired the form of a deep "S" (Fig. 10, top). In one patient who underwent an excision of carcinoma of the soft palate, irregularity of the velum and mucosal folds from the velum to the lateral pharyngeal walls were clearly demonstrated during FST (Figs. 9, 10).

Passavant's ridge. Passavant's ridge was found in seven of the patients (Table I). In one patient, the ridge was veiled by the velum during speech and was fully observed during FST, allowing its accurate observation (Fig. 11) as was seen in the individuals with

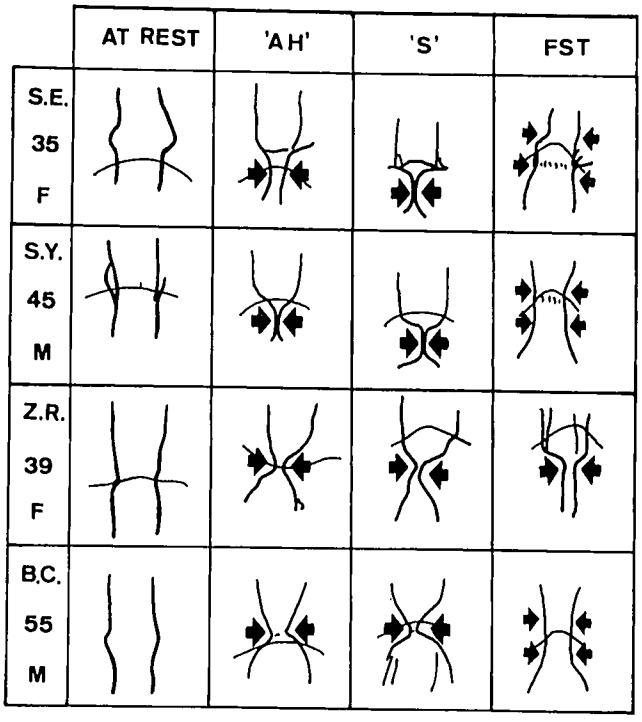

Fig. 6. Frontal view of the velopharyngeal valve at rest, during phonetic activity, and FST. The medial movement of the lateral pharyngeal walls is indicated by the arrows. The tongue is indicated by the horizontal traces.

a normal VP valve. In one patient, the ridge appeared during speech and was not found in FST. On radiological examination, the ridge was found in speech in all patients. Endoscopically, the configuration and the level of the ridge were constant during various activities, including the FST (Fig. 11). Similarly, the radiological study showed that the shape and positional relationship of the ridge to the tubercle of the atlas remained essentially constant in each individual (Figs. 8, 10). In seven patients, the ridge was observed on the posterior pharyngeal wall, and the posterolateral angles merged posteriorly to the salpingopharyngeal folds (Figs. 11, 12). The medially oriented movement of the entire lateral pharyngeal walls was observed during FST in the other cases with Passavant's ridge. In the patient with an excision of carcinoma of the soft palate, a coronal closure pattern with Passavant's ridge was found (Fig. 12).

DISCUSSION

There is an ever-increasing demand to expand the fiberoptic nasendoscopic examination of the VP valve. This study describes the contribution of assessing the VP valve in nonphonetic activity, *i.e.*, forced sucking, as complementary to the examination in speech. FST provides information about anatomy and function, emphasizing the VP impairment and the extent of the morphologic defect. Harmonic function of the VP muscles is essential for speech and nonphonetic activities.[10,15] There is a difference, how-

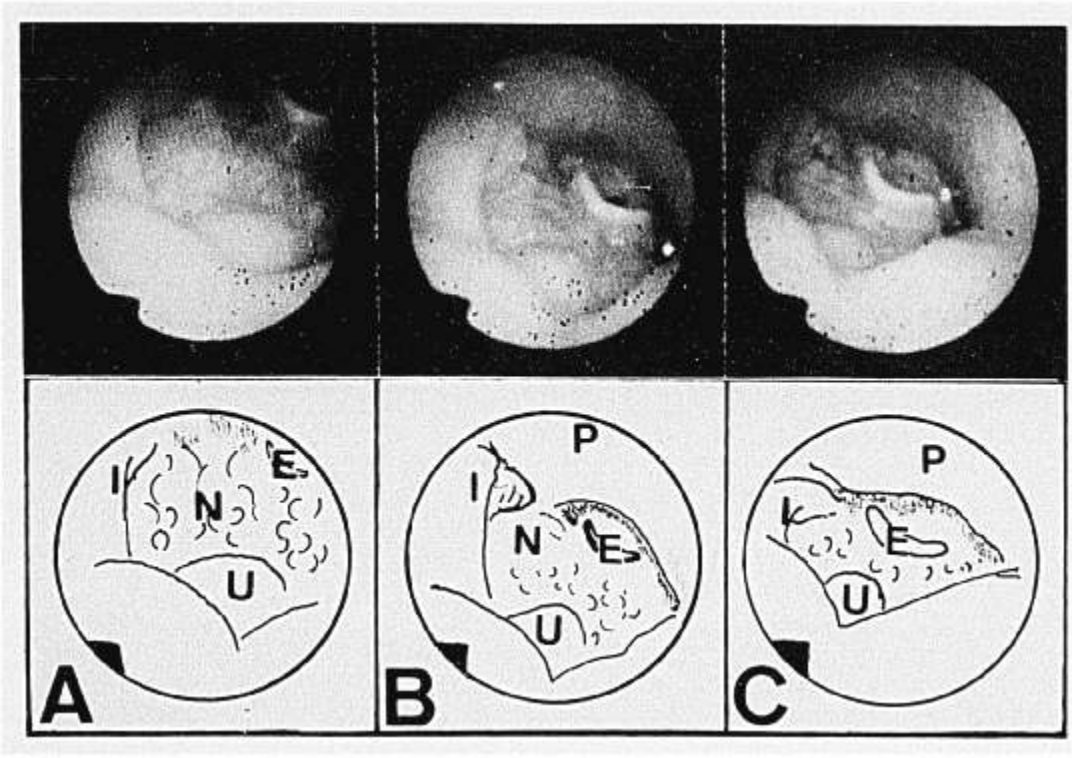

Fig. 7. Endoscopic view of the velopharyngeal valve in a girl with an occult submucous cleft palate at rest (**A**), during producing of */ah/* (**B**), and during FST (**C**). E = epiglottis; I = posterior tonsillar pillar; N = base of tongue; U = uvula. The convexity on the midline of the velum is indicated by the arrow of the endoscope.

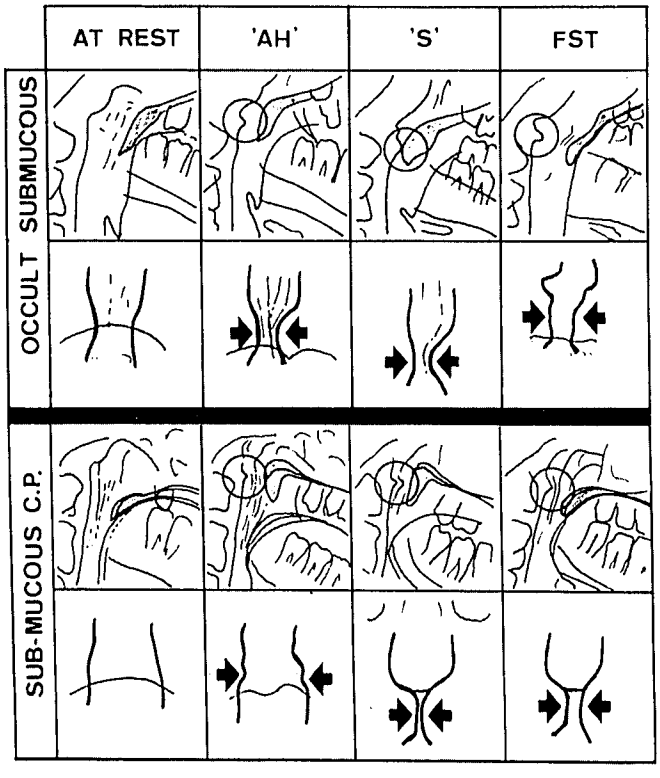

Fig. 8. Lateral and frontal radiographic image of the velopharyngeal valve of patients with occult (**top**) and submucous (**bottom**) cleft palate. The activities performed are noted on the horizontal axis. In the lateral view, Passavant's ridge is indicated by the circle. In the frontal view, the medial movement of the lateral pharyngeal walls is indicated by the arrows, and the dorsum of the tongue is indicated by the horizontal traces.

ever, between the tridimensional harmonic function of the VP valve muscles in phonetic and nonphonetic activities.[16,17] Speech, blowing, and whistling are all pneumatic activities and are acquired abilities of the VP valve,[13] contrary to sucking and swallowing, which occur as early as the prenatal period.[18] In speech, the pharyngeal muscles function under the control of the left cerebral hemisphere,[19] while sucking and swallowing closure are regarded as being reflexive in nature.[20]

In the present study, the dynamics of the VP valve during forced sucking were studied and compared to the phonetic activity. It was found that 80% of the patients with Passavant's ridge in speech were able to selectively exhibit the ridge in FST. Fletcher[21] found that 3 out of 10 normal children produced Passavant's ridge during both phonation and swallowing. In the present study, it was found that the ridge appeared in the phase of forced sucking and remained during the oral and pharyngeal phases of deglutition. As shown by Karnel, *et al.*,[4] Passavant's ridge can be veiled during speech by the velar elevation and medial movement of the lateral pharyngeal walls.

Several theories have been proposed to explain the formation of Passavant's ridge.[3,22–28] One of the two major theories was espoused by Passavant, who attributed the formation of the ridge to the palatopharyngeus muscle; the other is that of von Luschka,[24] who considered the superior constrictor muscle as the origin of Passavant's ridge. The anterior movement of the ridge in FST is generally seen as a distinct structure on the posterior pharyngeal wall, not in

Fig. 9. Lateral radiographic view of the velopharyngeal valve during FST in a patient with pharyngeal flap (**left**) and following excision of carcinoma (**right**). The arrows indicate Passavant's ridge.

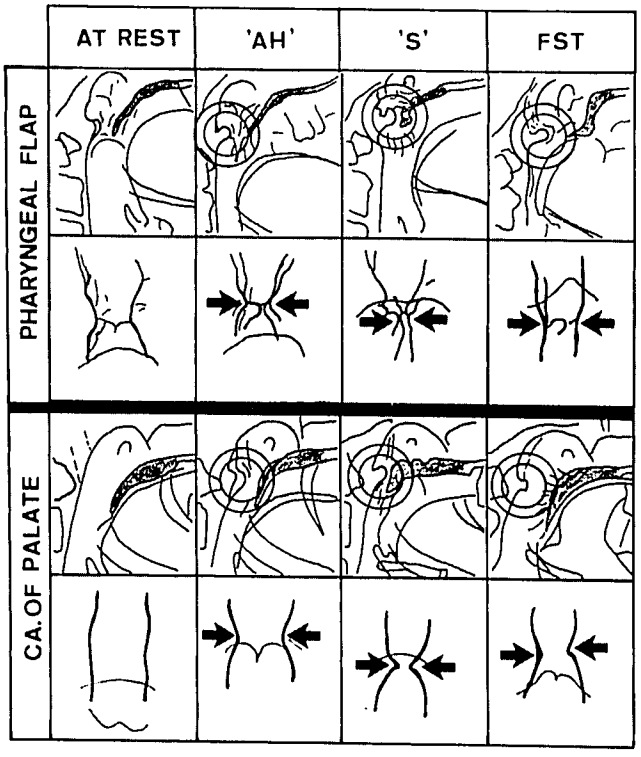

Fig. 10. Lateral and frontal radiographic image of the velopharyngeal valve in patients with pharyngeal flap (**top**), and in a patient who underwent excision of carcinoma of the soft palate (**bottom**). The activities performed are noted on the horizontal axis. In the lateral view, Passavant's ridge is indicated by the concentric circles. In the frontal view, the medial movement of the lateral pharyngeal walls is indicated by the arrows, and the dorsum of the tongue is indicated by the horizontal trace.

continuum with the mobile part of the lateral pharyngeal walls. In the radiological examination, the medial movement of the lateral pharyngeal walls is not essentially different from this movement in cases without Passavant's ridge.

This observation suggests that, in these cases, the ridge is formed by the superior constrictor muscle rather than the palatopharyngeus. Fritzell[29] found that, during sucking, the palatoglossus muscle is always active, while the other muscles are infrequently so. The palatoglossus actively pulls the palate down and elevates the middle and posterior parts of the tongue. This muscle has the opposite function to the levator veli palatini and the palatopharyngeus muscles, opening the VP valve for nasal sound and for nasal breathing. The most important muscle in speech is the levator veli palatini, and the activity of the superior constrictor is associated with that of the levator.[29] Thus, the levator veli palatini and the palatopharyngeus muscles are not active during FST.

This functional analysis supports the theory that Passavant's ridge in these cases is formed by the superior constrictor, which is active both in speech and in deglutition. Different mechanisms are probably responsible for the formation of Passavant's ridge. When the ridge is formed in FST and is localized on the posterior pharyngeal wall, it is formed by the superior constrictor muscle. When the ridge appears in FST and is associated with the medial movement of the lateral pharyngeal walls, it is formed by the superior constrictor which inserts in the velum in these cases.[30–32] During speech, the activity of the superior constrictor muscle assists the levator veli palatini muscle. The latter is responsible for the velar and probably the lateral pharyngeal walls' movement,[33,34] contributing to the VP valve closure.

In cases where the ridge does not appear in FST, it could be formed by the palatopharyngeus muscle only. Endoscopic and radiological examinations revealed that movement of the ridge was identical during phonetic activities and FST. The FST can improve the visualization of the ridge in a routine nasendoscopic examination of the VP valve.

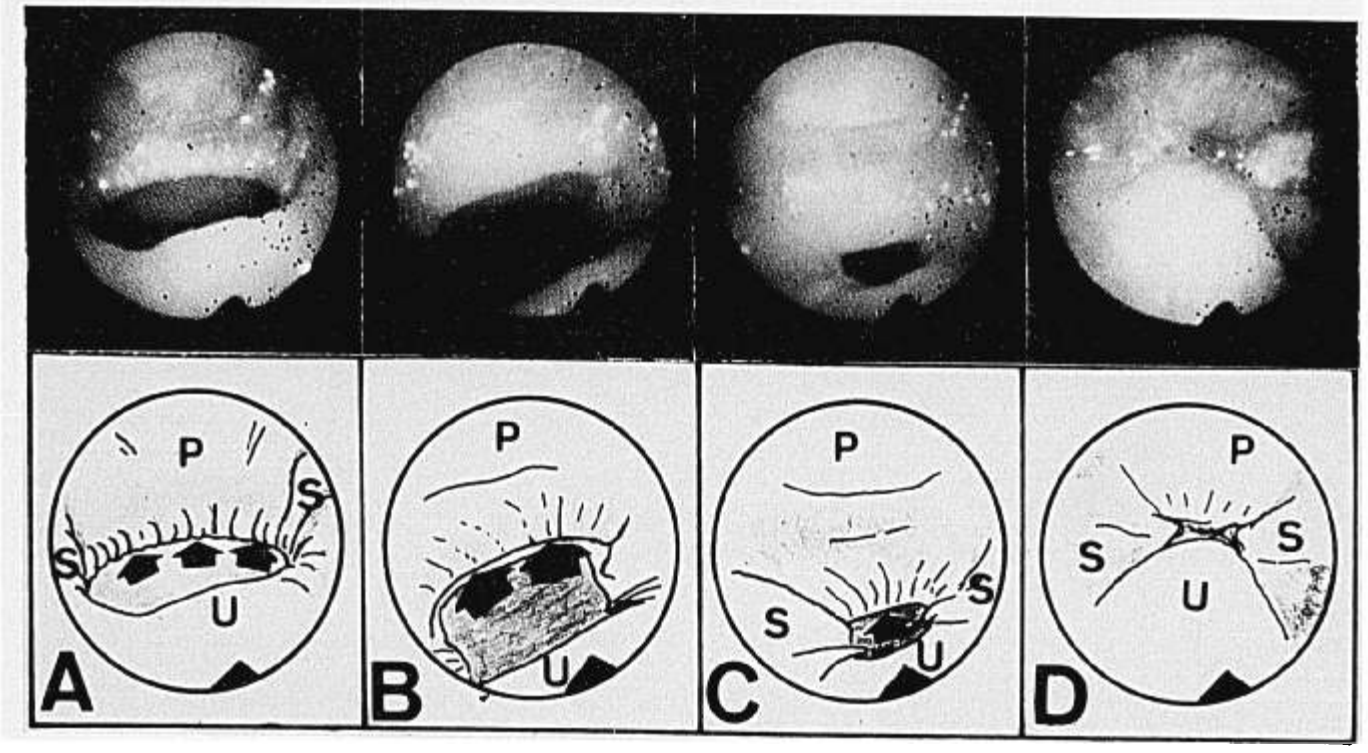

Fig. 11. Endoscopic view of Passavant's ridge in a submucous cleft palate during FST (**A**), during production of /*ah*/ (**B, C**), and during production of /*s*/ (**D**). P = posterior pharyngeal wall; S = salpingopharyngeal wall; U = velum. The arrows indicate the Passavant's ridge.

The role of Passavant's ridge is important in the closure mechanism of the VP valve. Zuitman[35] suggested that, following pharyngeal flap surgery, pharyngeal contraction can be significantly reduced because the elevation of the muscles to create the pharyngeal flap opens the ring formed by the superior constrictor muscle. In such cases, the flap should be excised under the plane of Passavant's ridge.

In cases of severe VP insufficiency, no movement can be found during speech. However, patients can easily attain sucking and swallowing closure of the VP valve[36] because they are reflexive in nature. This is an important advantage, since occult submucous cleft palate can only be detected nasendoscopically during functioning of the palate. The diagnosis of velar diastasis can be difficult. Lax tissue, which normally surrounds the muscularis uvulae,[37,38] fills the medial space of the velum with no contractile muscular tissue and may mislead the endoscopist.

Some cases with VP insufficiency are defined as "idiopathic" even after accurate investigation. These cases comprise about 19% of the patients.[39] It is believed that by application of FST, the exact diagnosis can be made, and the number of "idiopathic" VP insufficiency cases will further decrease. This test enables accurate evaluation following surgical management of the palate and confirms the diagnosis of velar musculature diastasis.

In cases of adenoidal hypertrophy and veloadenoidal closure, it is impossible to observe the VP valve at maximal closure or closure approximation. Croft, *et al.*,[40] in examining 120 patients with hypernasal speech after adenotonsillectomy, found that removing the adenoids in patients with occult or overt submucous clefts was the primary cause of VP insufficiency in their sample population. This finding was subsequently confirmed by Witzel, *et al.*[41] Therefore, endoscopic assessment of the VP valve has great importance in young candidates for adenoidectomy when occult submucous cleft palate is suspected. In these cases, the FST is a valuable adjunct in establishing the diagnosis of velar defect. Experience has shown that normal nasendoscopy and FST excluded VP malformation in candidates for adenoidectomy with suspected VP insufficiency. None of these children developed VP insufficiency following adenoidectomy.

CONCLUSION

Additional information about the structure and function of the VP valve is obtained by the endoscopic FST.

1. Passavant's ridge is equal in shape and location in the same patient during FST and speech.

2. In 80% of the patients manifesting Passavant's ridge in speech, it appeared during FST. The Passavant's ridge was never found during FST in patients with no ridge in speech.

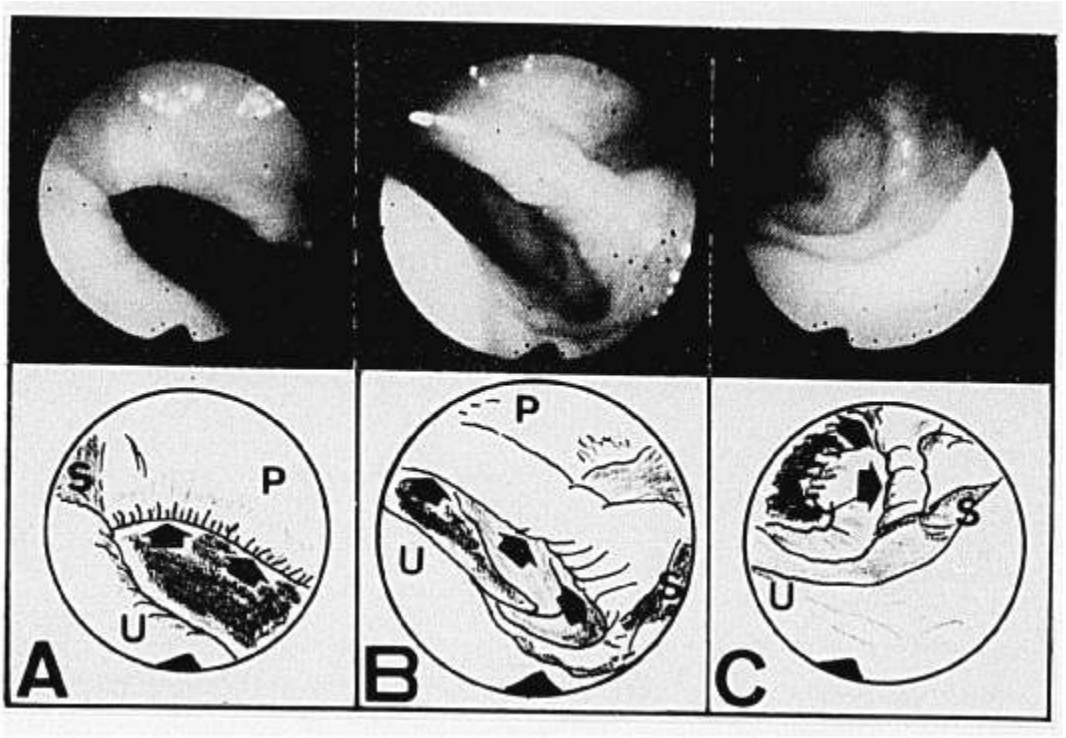

Fig. 12. Endoscopic view of a patient who underwent excision of carcinoma of the left soft palate. **A.** Right portal region. **B.** Central view. **C.** Left portal region. P = posterior pharyngeal wall. S = salpingopharyngeal fold. U = velum. The arrows indicate Passavant's ridge.

3. The formation of Passavant's ridge during FST and its location on the posterior pharyngeal wall, indicate that the ridge is formed by the superior constrictor muscle.

4. The advantages of the FST are selective observation of the Passavant's ridge, diagnosis of diastasis of the velar musculature in cases of limited velar movement in phonetic activity, and observation of velar musculature in the presence of adenoidal hypertrophy which ordinarily limits its visualization.

The application of the FST in the routine endoscopic examination of the velopharyngeal valve is recommended.

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