Oral-pharyngeal Movements During Swallowing and Speech

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Several investigators have observed that cleft palate individuals who do not have adequate velopharyngeal closure for speech nevertheless demonstrate the ability to prevent regurgitation of the bolus during swallowing (*1, 3, 4, 8, 9*).

Shelton, Brooks and Youngstrom (*8*) described a mechanism used during swallowing by cleft palate children which they referred to as a "free fall of the bolus". They observed cinefluorographically that, in some cases, as the bolus flows over the posterior slope of the tongue, there is little or no tongue movement. After the "free fall", the bolus is moved into the esophagus by the tongue pressed against the pharyngeal wall. The tongue may or may not move up to contact the soft palate during this action. They suggested that the "free fall" phenomenon is compensatory for poor palatopharyngeal closure.

Moll (*7*) reported that five subjects with repaired cleft palate and gross velopharyngeal inadequacy during speech were able to achieve velopharyngeal closure during swallowing. Tongue-palate valving was suspected as the mechanism used to obtain velopharyngeal contact. He noted that his cleft palate subjects, in contrast with the noncleft palate subjects, exhibited more anterior pharyngeal wall movement in swallowing than in speech.

The purpose of this study was to provide a detailed description of oral-pharyngeal movements during deglutition in selected normal and cleft palate subjects, and to describe similarities and differences in velopharyngeal function during swallowing and during speech.

Procedures

SUBJECTS. Two children with cleft palate (surgically repaired) and two normal children were the subjects for this study. Each was an eight-year-old male judged by an orthodontist to have normal occlusion. One cleft palate subject was selected to demonstrate adequate velopharyngeal contact during speech, and one was selected to demonstrate inadequate velopharyngeal contact during speech, as observed cinefluorographically.

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Cinefluorographic Procedures. The cinefluorographic equipment and the subject positioning procedures have been described by Kent and Moll (*6*). Subjects were first filmed at a camera speed of 24 frames per second while producing a sustained /u/ and /s/ and while reading three sentences. Subjects were then filmed at a camera speed of 100 frames per second during two swallows of a mouthful of a mixture of barium and water. They were instructed to take in a mouthful of liquid, hold it momentarily, and then swallow.

Analysis of Speech Samples. Certain portions of each sentence were selected for analysis according to the criteria that velopharyngeal contact was expected and some articulatory movements could be identified easily for each subject during that portion of the sentence. In addition, films of the prolonged /u/ and /s/ were analyzed.

Structures traced were the velum, tongue, central incisors, pharyngeal wall, hyoid bone, and whatever bony structures were easily identifiable for each subject in the region superior to the inferior surface of the hard palate. Measurements were made of (a) the shortest distance between the posterior surface of the velum and the posterior pharyngeal wall, (b) amount of velar movement from the velum-at-rest position to the maximal height position, and (c) extent of velopharyngeal contact. In addition to the measurements, an analysis was made of the path of velar movement during the prolonged /u/ and /s/ and during the sentences. This was determined by superimposing the tracings of the frames in which velar elevation was observed.

Analysis of Swallows. The films of the two swallows for each subject were traced frame-by-frame. The initial frame traced was that frame which was five frames ahead of the one in which the first forward and upward tongue movement was observed, following the interim of holding the bolus in the mouth. Each frame of the swallow was then traced until it was observed that the velum, tongue and hyoid bone had returned to pre-swallow positions, or until the film of the swallows terminated. (The latter criterion was necessary, since, by error, filming was terminated for some of the swallows before all of the structures had returned to pre-swallow positions.) The same structures were traced for the swallows as for the speech tasks. The bolus was also traced. Tracings were observed by superimposition to provide a description of the movements of the velum, tongue, pharyngeal wall, mandible and bolus. Specifically, interest was in describing the timing and patterns of movement of the observed structures relative to each other, and relative to the position of the bolus. Observations were made of amount of velar movement toward the pharyngeal wall, angle of velar movement, and amount of velopharyngeal opening; extent and direction of tongue movement and tongue configuration; bolus position; amount and location of posterior pharyngeal wall movement, and extent of incisor opening.

Results

Reliability of Tracings and Measurements. A reliability estimate of the measurements for speech tasks was obtained by retracing and remeasuring at least 50 frames chosen randomly from the sentences and during the prolonged /u/ and /s/. The standard error for a given measure was computed; they ranged from 0.5 (velar movement, S #3) to 1.77 (extent of velar contact, S #4).

Intra-judge reliability of the tracings for the swallows was estimated by retracing at least 50 frames from each swallow for each subject. Superimposition of these tracings with the original tracings revealed small differences that were not believed to be critical to the analysis. In addition, an estimation of inter-judge reliability was obtained by having another person trace every fifth frame of the first swallow for each subject. These tracings were superimposed on the original tracings, and no differences considered important to this analysis were observed.

Velar Function during Speech Tasks. Analysis of the measurements revealed that the normal subjects demonstrated fewer velopharyngeal openings and greater extents of velopharyngeal contact during all of the speech tasks than either of the cleft palate subjects. Of the two cleft palate speakers, one subject did not evidence closure on any of the speech tasks, but the other subject achieved closure or demonstrated smaller velopharyngeal openings than his counterpart on all speech tasks.

Swallowing Patterns. In general, the patterns and timing of structural movements during the two swallows for a specific subject were similar. Therefore, results of the analysis consist primarily of a description of swallow 1 for each subject. For each cleft palate subject, selected tracings are shown for both swallows in Figures 1 and 2. For each normal subject, tracings are shown for only swallow 1 (Figures 3 and 4), since for those normal subjects swallow 1 and swallow 2 were almost identical. Detailed descriptions of the swallows for each subject are reported by Flowers (*5*).

Subject 1 (Cleft Palate, with Velopharyngeal Incompetence during Speech)

During swallow 1 (Figure 1, top), by the time the bolus was situated on the posterior aspect of the tongue and about to spill over the epiglottis, the orientation of the dorsal tongue surface was nearly vertical (Frame 84). The tongue continued to change configuration as the bolus began spilling over the epiglottis and was extending from the epiglottis up to the level of the juncture of the hard and soft palates (Frame 100). The velum continued ascending as the bolus descended the mesopharynx (Frames 124 and 131).

While the bolus travelled over the dorsum of the tongue and the epiglottis, the tongue was observed moving upward and backward, eventually contacting the velum (Frame 150). Velopharyngeal contact was observed coincidentally with tongue-velum contact. Velopharyngeal contact continued to be observed during frames 150–178 (not shown). Pharyngeal wall movement was noted immediately below and at the level of velopharyngeal contact prior to and during velar movement toward the pharyngeal wall.

As the bolus lowered past the epiglottis, the tongue dorsum moved in a superior-posterior direction, eventually contacting the pharyngeal wall (Frame 181). The highest point of tongue-pharyngeal wall contact was at the level of the second cervical vertebra. Tongue-velum contact was maintained as the tongue moved toward the pharyngeal wall. As the bolus descended into the upper esophagus, tongue-pharyngeal wall contact was made lower and more extensively on the pharyngeal wall. The velum descended and continued to make contact with the tongue as tongue-pharyngeal wall contact was observed at progressively lower positions (Frame 187).

The mandible remained stable during the entire swallow. Incisor opening during the swallow measured 7–8 mm.

During the second swallow of Subject 1 (Figure 1, bottom), one segment of the bolus was held on the anterior portion of the tongue while the remainder was swallowed (Frames 68, 73 and 80).

The timing and patterns of movement of the pharyngeal wall were observed to be similar during swallows 1 and 2. However, the tongue and velar movement showed different patterns during the two swallows. Relative to the position of the bolus, velar elevation began earlier during swallow 2 than during swallow 1. During the entire

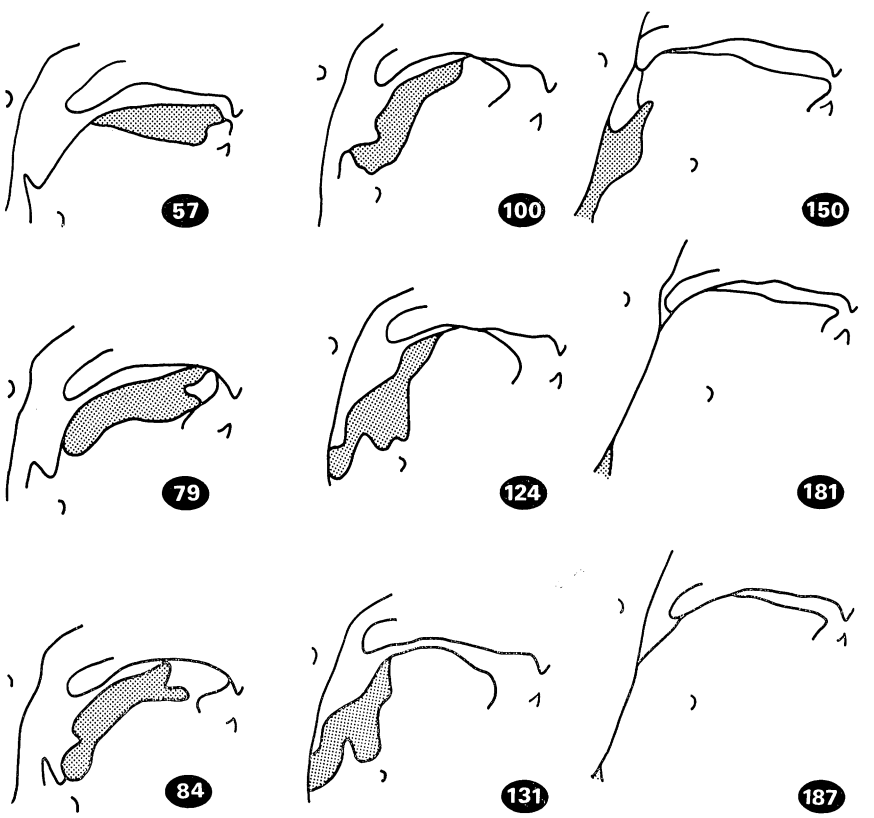

FIGURE 1. Selected tracings of cinefluorographic frames filmed during swallow 1 (top) and swallow 2 (bottom) of Subject 1 (cleft palate subject with velopharyngeal incompetence during speech). The number in the corner of each picture identifies the frame number.

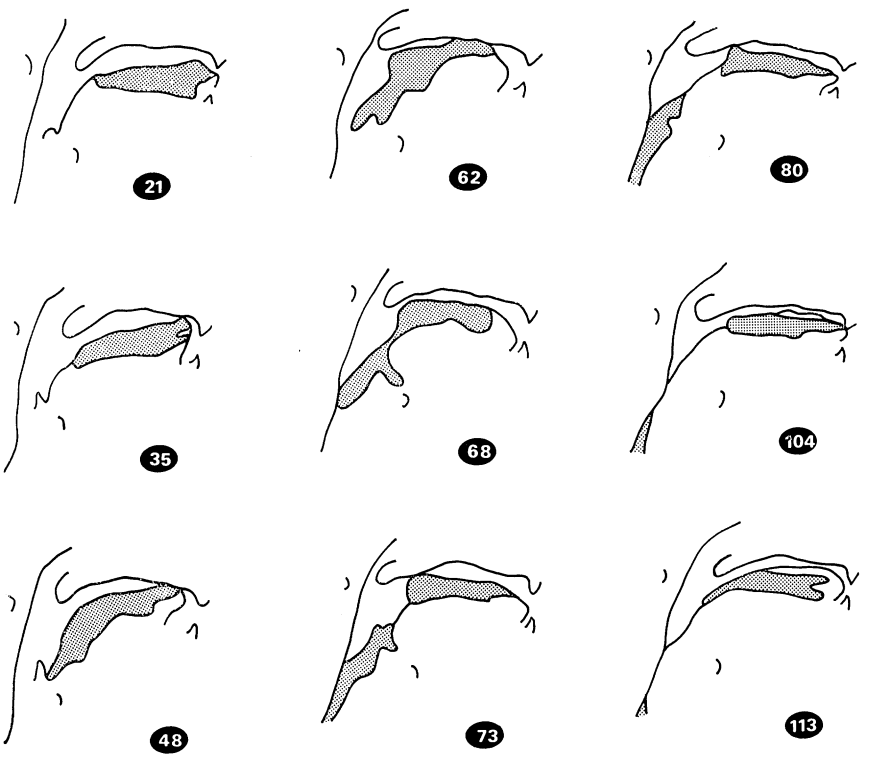

FIGURE 1 (bottom)

swallow 2, neither velopharyngeal contact nor tongue-palate contact was observed, although the velum elevated to within a 2 mm velopharyngeal (VP) distance.

Tongue-pharyngeal wall contact was made during swallow 2 at a somewhat lower level than during swallow 1, and the contact was not as extensive during swallow 2 as during swallow 1.

Subject 2 (Cleft Palate, with Velopharyngeal Competence during Speech)

During the first swallow (Figure 2, top), the initiation of velar ascent was first observed as the bolus approached the fauces (Frame 32). Velopharyngeal contact was made before either the bolus or the tongue made contact with the velum (Frame 39). The contact was observed until the tail of the bolus was approximately the level of the third cervical vertebra (Frame 54). Although the velum remained in an elevated position throughout the remainder of most of the swallow, velopharyngeal contact was not observed again.

As the bolus descended the pharynx, the tongue moved back and up to contact the velum (Frame 54). This contact was observed during 15 frames. Tongue-velum contact was withdrawn, and the dorsum of the tongue moved back to approximate contact with the pharyngeal wall (Frame 76). The tongue continued to move posteriorly to contact the pharyngeal wall (Frame 84). During the period of observed velopharyngeal contact, pharyngeal wall movement was observed in the area of contact.

During most of the swallow, the tip of the tongue was situated between the

incisors. The distance between the central incisors remained at approximately 8 mm during the entire swallow.

The pattern of pharyngeal wall movement was observed to be essentially the same during swallows 1 and 2. Likewise, velar elevation began at approximately the same time relative to bolus position during each of the two swallows. During swallow 2 (Figure 2, bottom), velopharyngeal contact was never observed, although the velum elevated to within a 2 mm distance of the pharyngeal wall (Frame 38).

The pattern of tongue movement was similar during swallows 1 and 2. During both swallows, the tongue moved back to a superior position immediately behind the bolus after the bolus had entered the pharynx. Tongue-palate contact was observed at this time for a brief period.

Subject 3 (Normal)

During swallow 1 (Figure 3), velar elevation began before the bolus had reached the region of the soft palate (Frame 18), and velopharyngeal contact was first observed when the bolus had just reached the dorsum of the tongue (Frame 34). Contact was observed for 35 frames, until the bolus was approximately in the position shown in Frame 72.

Immediately after velopharyngeal contact was noted, the tongue moved upward and backward and the bolus was observed in contact with the velum (Frame 39). When the bolus was past the region of the velum and was in the mesopharynx, the

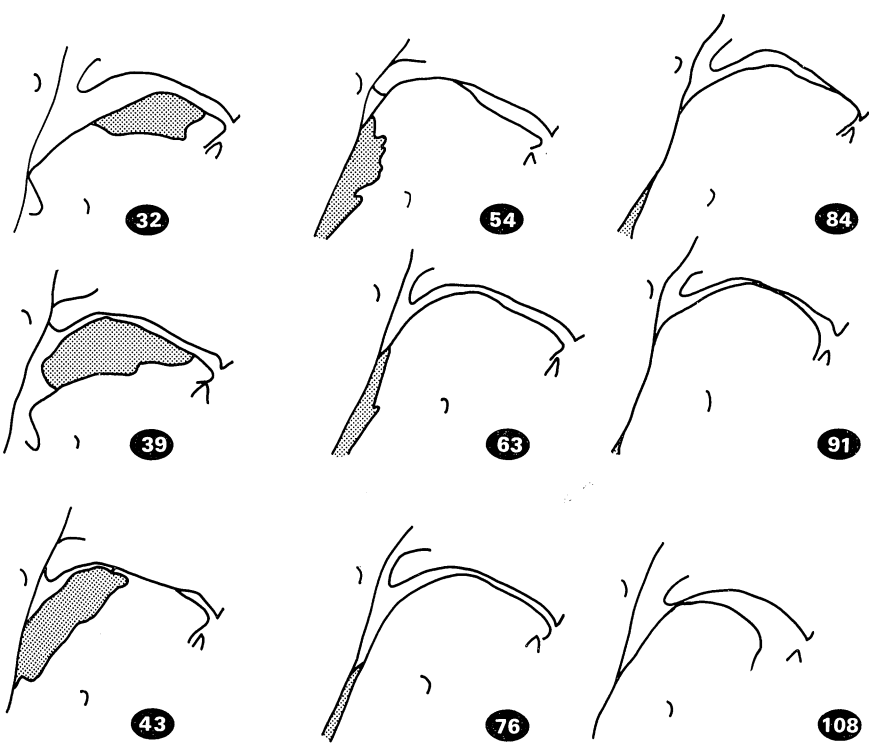

FIGURE 2. Selected tracings of cinefluorographic frames filmed during swallow 1 (top) and swallow 2 (bottom) of Subject 2 (cleft palate subject with velopharyngeal competence during speech).

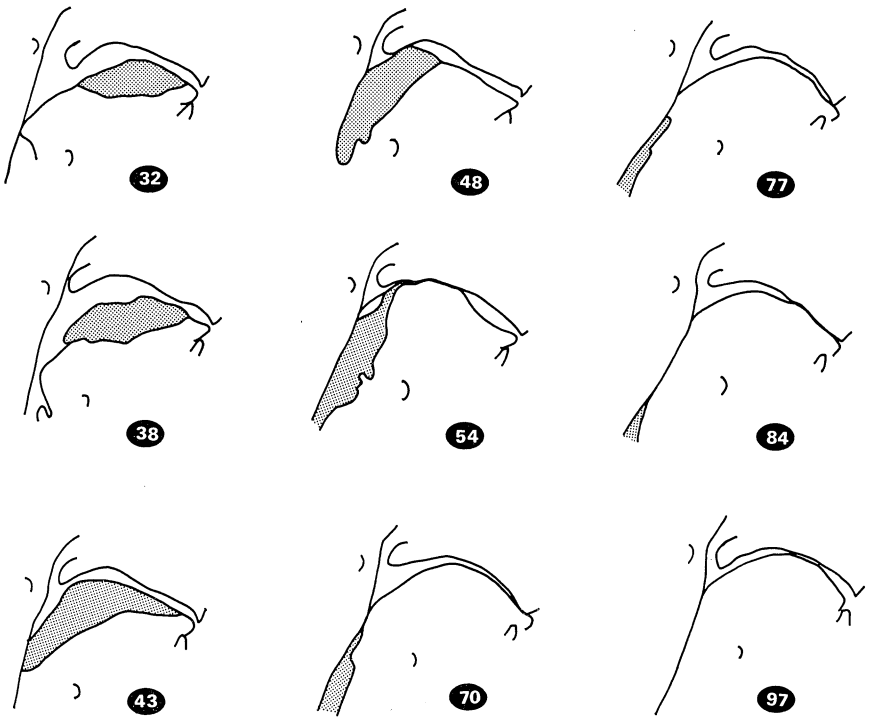

FIGURE 2 (bottom)

tongue began to move back to contact the velum and pharyngeal wall (Frames 58, 72 and 81).

No pharyngeal wall movement was observed in the area of velopharyngeal contact. However, pharyngeal wall movement was observed lower in the pharynx at and below the level of the third cervical vertebra, progressing downward behind the bolus as the bolus descended.

Little jaw movement was observed during the entire swallow. Incisor openings measure 3 to 5 mm.

The direction, amount and time of structural movements were observed to be similar during swallows 1 and 2 for Subject 3. The velum moved to a position of closure at the same time during both swallows, relative to tongue and bolus positions. Tongue configurations were essentially the same during both swallows, and pharyngeal wall movements showed the same patterns and timing.

Subject 4 (Normal)

The pattern of structural movements for Subject 4 (Figure 4) were similar to those described above for Subject 3. There was little difference between the two swallows of Subject 4 in direction, amount, and timing of the movements of the bolus and the observed structures.

Comparison of Velar Movement in Speech and Swallowing. During swallow 1 for Subject 1, the velum moved to a higher position during swallowing than during speech. The paths of velar movement for that

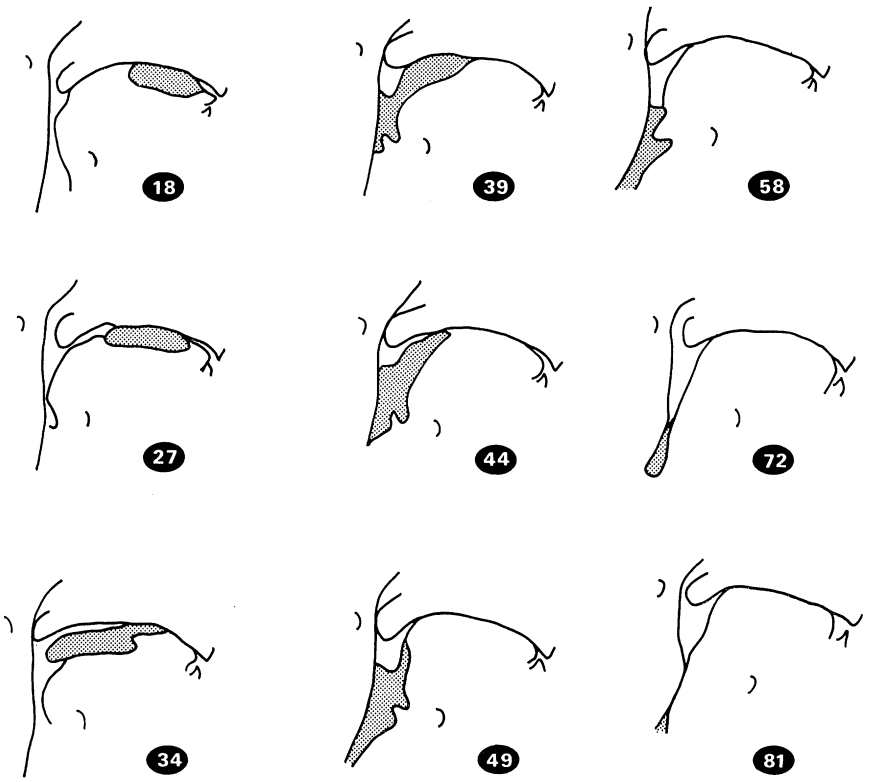

FIGURE 3. Selected tracings of cinefluorographic frames filmed during swallow 1 of Subject 3 (normal subject).

subject during swallow 2 and speech were the same, although more pharyngeal wall movement, and thus a smaller velopharyngeal opening, was observed during swallow 2 than during speech. Differences between maximal velar movement during swallowing and during speech were negligible for Subjects 2, 3 and 4.

Subjects 1 and 2, the cleft palate subjects, demonstrated greater extents of pharyngeal wall movement at the level of velopharyngeal contact during speech and swallowing.

Discussion

Patterns of the two swallows for each normal subject were similar with regard to all of the observations made in this study, but there was considerable variance between the two swallows of each cleft palate subject. The inconsistencies between swallows, particularly of the cleft palate subjects, indicate that more than one sample of deglutition pattern is needed for a subject in order to obtain reliable descriptions of deglutition patterns.

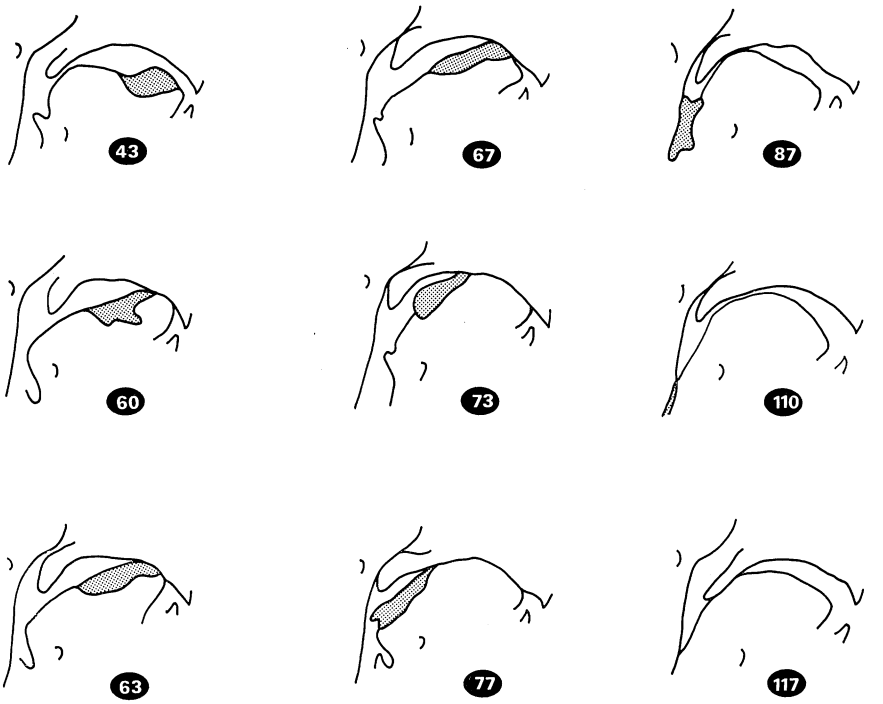

FIGURE 4. Selected tracings of cinefluorographic frames filmed during swallow 1 of Subject 4 (normal subject).

Subject 1 showed no velopharyngeal contact for speech, but nevertheless he did achieve velopharyngeal contact during one swallow, apparently by means of tongue-velum contact. Velopharyngeal contact was not observed until tongue-velum contact was observed. In addition, when the tongue lowered (after it had been in contact with the upper pharyngeal wall and the velum), the velum also began to lower. During the second swallow, when tongue-velum contact was not observed, neither was velopharyngeal contact.

Subject 2 achieved velopharyngeal closure during speech and during one of his two swallows. Velopharyngeal contact was achieved during swallowing without the aid of tongue-velum press, and the path of velar movement during speech and swallowing were very similar.

One of the characteristics of deglutition in cleft palate individuals observed by Shelton, Brooks and Youngstrom (*8*) was that the bolus moves to a relatively low position in the hypopharynx before tongue-pharyngeal wall contact occurs. "Thus", state the authors, "the bolus is not so likely to be squeezed upward into the nasal cavity by tongue-pharyngeal wall press" (p. 209).

For the cleft palate subjects in the present study, the bolus *was* observed to be in a low position in the hypopharynx *before* tongue-pharyn-

geal wall contact was noted. However, the position of the bolus when tongue-pharyngeal wall contact was noted was no lower for the cleft palate subjects than for the normal subjects. There also was no tendency for the bolus to be further removed from the palate during deglutition for the cleft palate subjects than for the normal subjects. It appears from these observations and from the occurrence of similar patterns of bolus descent and tongue-pharyngeal wall contact in one of three normal subjects in the Shelton, Brooks and Youngstrom study (*8*, p. 208), as well as in the subjects of Ardran and Kemp (*2*), that the "free fall" mechanism is not peculiar to the cleft palate population. Therefore, the process does not appear to be "compensatory" in cleft palate subjects, even though it *may* indeed assist somewhat in preventing nasal regurgitation in those subjects.

When a cleft palate subject shows velopharyngeal closure during swallowing, one should not necessarily expect the velum also to effect closure during speech for the following reasons (there may be others). a) Some subjects demonstrate greater amounts of pharyngeal wall movement in swallowing than they do in speech, and that pharyngeal wall movement aids in effecting velopharyngeal competence during swallowing. b) Some subjects achieve velopharyngeal competence during swallow by "tongue-velum press" and this tongue-velar combination of movements cannot be used effectively during speech. c) The time relationships with which the velum works are apparently different for speech and swallowing. For some speech activities, velopharyngeal competence is maintained for a considerably longer period of time than is usual for swallowing. Also, for some speech activities, the rate of velar elevation and descent must be faster during a given period of time than is ever required during swallowing.

The differences between velar functioning during speech and during swallowing and other non-speech activities indicate that the use of non-speech activities is of questionable validity in evaluating and exercising the velopharyngeal mechanism.

Summary

The purpose of this study was to provide a detailed description of oral-pharyngeal movements during swallowing in selected normal and cleft palate subjects. Results indicate that successive swallows of a subject may show important differences in the relative timing and amount of velar movement. Thus, one swallow may not adequately represent structural movement patterns in deglutition for a particular subject, especially regarding velar function. Evidence was provided that some cleft palate subjects, who do not achieve velopharyngeal closure during speech, achieve closure during swallowing by the use of tongue-velum press and increased pharyngeal wall movement. There was no evidence to indicate that the mechanism described as bolus "free fall" is a compensatory mechanism in the cleft palate population. The mechanism does not appear

to be peculiar to the cleft palate population. Differences between velar functioning during speech and swallowing are discussed.

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