Patterns of Velopharyngeal Closure in Subjects with Repaired Cleft Palate and Normal Speech: A Multi-View Videofluoroscopic Analysis.

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A review of the literature dealing with radiographic observations of the velopharyngeal closure apparatus indicates that there are essentially two categories of scientific investigations. There have been numerous studies of the patterns of closure in subjects with velopharyngeal incompetence (*2, 4, 5, 6, 7, 8, 10, 14, 16, 17, 18*) and studies of patterns of closure in normals (*7, 10, 11, 13, 15*). There is, however, a third category which as yet has not been explored. That is, studies of patterns of velopharyngeal closure in subjects with repaired cleft palates and normal speech.

Skolnick (*16, 17*) and others (*1, 3, 9, 13*) have stressed the importance of analyzing velopharyngeal closure in terms of both velar movements and the medial movements of the lateral pharyngeal walls. Skolnick, et al. (*18*) regard velopharyngeal closure as basically a sphincteric mechanism, which can only be adequately described by a multi-view fluoroscopic procedure. Shprintzen, et al. (*13*) point out that lateral view radiographic procedures are limited since they are two dimensional representations of a three dimensional process, which can only be adequately described utilizing a minimum of two fluoroscopic projections. Shprintzen, et al. (*15*) described velopharyngeal closure for speech in normal adult subjects as involving the postero-superior movement of the velum, approximating to the posterior aspect of the pharyngeal walls (PAPW) at a point below the levator eminence, and the medial movement of the lateral aspects of the pharyngeal walls (LAPW) approximating to the lateral edges of the velum. The medial movements of the LAPW occurred primarily at a specific select level, resembling a shelf in the LAPW at the plane of the hard palate. This shelf-like pattern was observed for all normal subjects studied.

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The purpose of this study was to describe the patterns of velopharyngeal closure as demonstrated videofluoroscopically in children with repaired cleft palate and no evidence of velopharyngeal insufficiency and speech within normal limits. Multi-view videofluoroscopy, performed at two cleft palate centers, was utilized for a complete three dimensional analysis of the movements of the velopharyngeal sphincters of cleft palate subjects.

Procedure

SUBJECTS. The subjects for this study were 30 children with varying types of repaired palatal clefts. The subjects consisted of a randomly selected portion of the case loads from the Cleft Palate Clinic at Upstate Medical Center, Syracuse, N. Y. and the Center for Cranio-Facial Disorders at Montefiore Hospital and Medical Center, Bronx, N. Y. The subjects included:

Submucous cleft palate:	1
Repaired partial cleft palate:	7
Repaired unilateral complete cleft lip and palate:	15
Repaired bilateral complete cleft lip and palate:	7

The subjects ranged in age from 2 to 12 with a mean age of 7.4 years. All of the subjects had competent velopharyngeal closure as assessed by multi-view videofluoroscopic examinations, and articulation within normal limits for age range. None of the subjects received any secondary surgical intervention, such as pharyngeal flap, teflon injection, or other pharyngoplasty.

EXPERIMENTAL PROCEDURE. The videofluoroscopic procedure utilized at both centers has been described elsewhere in detail (*14, 16, 17*). There were some minor differences in the equipment between the two centers (for example, the TV line rate at Upstate was 525 while at Montefiore it was 945). However, these minor differences did not alter the quality of the recordings appreciably. All videofluoroscopic examinations were recorded on one inch video tape (SONY EV 210 and EV 320) with simultaneous sound. Examinations were recorded in three fluoroscopic projections and in some cases four. Lateral, frontal, and base projections were typically recorded for all subjects, though oblique views, enabling the visualization of the interaction between one lateral pharyngeal wall and the lateral edge of the velum, were recorded for several subjects. All videofluoroscopic examinations were performed with barium instilled intranasally to better define the margin of the velum and LAPW.

Video tapes of the multi-view fluoroscopic examinations were reviewed by the four experimenters, all experienced with the multi-view procedure, in full speed, slow motion, and stopped frames. Patterns of velopharyngeal closure were observed and noted and tracings were made of stopped frames for all views for all 30 subjects during at least four different samples of connected speech. For those subjects where head movement and movement of the fluoroscope were not a factor, lateral and frontal, and on occasion, oblique views were synchronized following the procedure of Shprintzen, et al. (*15*) in order to determine the relationship of the movements of the velum to the level of maximum medial excursion of the LAPW. This procedure was implemented for 12 subjects.

In an additional procedure, measurements were made to determine the consistency of both velar elevation and medial movement of the LAPW following the procedure of Shprintzen, et al. (*13*) in lateral and frontal views. One measure of velar height in lateral view and seven measures of LAPW movement in frontal view were recorded for each subject during three repeated utterances of /p/, /t/, /k/, and /s/ phonemes during connected discourse. The video image was stop framed during the utterance of the particular phoneme for the measurement procedure. A within subject statistical analysis was performed by the following series of orthogonal planned contrasts (*19*):

$$\mu/p/ = \mu/t/ \text{ or } \mu/p/ - \mu/t/ = 0$$
$$\mu/k/ = \mu/s/ \text{ or } \mu/k/ - \mu/s/ = 0$$
$$\frac{\mu/p/ + \mu/t/}{2} = \frac{\mu/k/ + \mu/s/}{2} \text{ or } \frac{\mu/p/ + \mu/t/}{2} - \frac{\mu/k/ + \mu/s/}{2} = 0$$

The raw data consisted of the measures in millimeters from the eight measurement lines in both views. F tests were performed for each hypothesis.

Results and discussion

The observed patterns of velopharyngeal closure seemed to show some obvious differences from those observed by Shprintzen, et al. (*13, 15*) for normal adult subjects (Figure 1). The difference was most apparent in lateral view. All of the 30 children were utilizing a prominent adenoid mass in the nasopharynx as a point of velopharyngeal closure as observed in lateral view (Figure 2). All 30 subjects closed between the superior surface of the velum and the inferior surface of the adenoid mass. Often a discrete levator eminance was not present due to the small space between the velum at rest and the adenoids. Thus, the velum had a limited distance to go in the vertical dimension before contacting the adenoids.

Out of the 30 subjects observed in this study, 10 had a Passavant's Ridge. In lateral view, all 10 of the subjects with a ridge closed at two points—on the adenoids, as described previously, and also between the posterior portion of the velum and the Passavant's Ridge (Figure 3). Of the 20 subjects without a ridge, 16 closed only against the adenoids, and 4 closed against both the adenoids and posterior pharyngeal wall.

Observing frontal and in some cases oblique views, it became quite evident that all 30 subjects had marked medial movement of the LAPW in a discrete

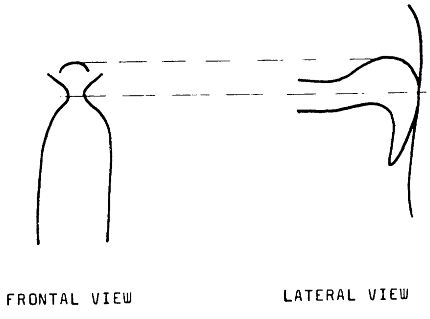

FIGURE 1. Frontal and lateral views of normal adult subject during speech.

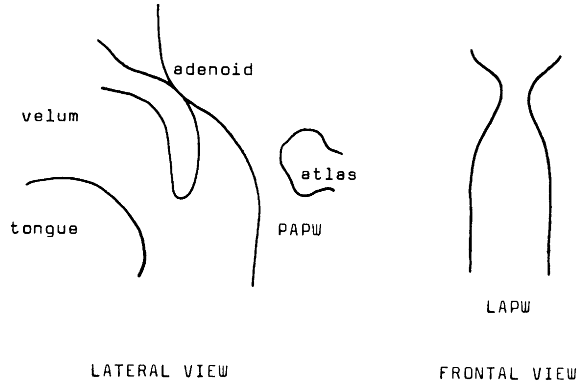

FIGURE 2. Lateral and frontal views of seven year old subject with repaired cleft palate and normal speech.

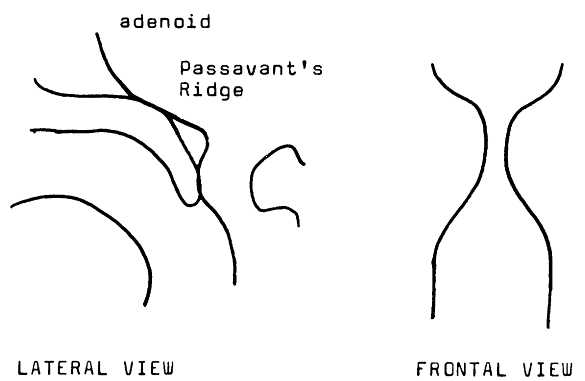

FIGURE 3. Lateral and frontal views of eight year old subject with repaired cleft palate, normal speech and Passavant's ridge.

localized area. Specifically, the synchronization procedure performed on 12 subjects showed that the level of maximum medial excursion of the LAPW occurred in an area corresponding to a 1 to 2 cm thick section connecting the posterior nasal spine to the anterior tubercle of the atlas (Figure 4). This section was at and below the level of the base of the adenoid mass. In addition, in 8 of the 30 subjects, the LAPW abutted in the midline just below the adenoid mass. Thus, the LAPW were abutting behind the velum presumably because the adenoid mass prevented the velum from inserting itself between the moving LAPW.

At first glance, it seemed that the velopharyngeal closure mechanism for this group of subjects was quite different from that observed in normals (*15*). As was noted at the beginning of this section, there were certain differences between this group and normal adults which became evident from lateral projection; velar-adenoidal closure and the absence of a well defined levator eminance. But basic similarities in the mode of closure between this group and normal adults show the closure mechanism to be the same. As described by Shprintzen, et al. (*15*), the level of maximum medial excursion of the LAPW occurs at the level of the hard palate and full length of the elevated velum (Figure 1). In the adult subjects, there has been midfacial growth resulting in an increase in the verticle dimension of the nasopharynx. The adenoids, if still present, now sit above the hard palate and above the level of closure. For the group of subjects observed in this study, however, the verticle height of the pharynx is more compressed, thus bringing the adenoids into the level of velopharyngeal closure. What is consistent between these two groups is the same type of sphincteric closure occurring approximately at the level of the hard palate. As illustrated in Figure 5, synchronization of lateral, oblique, and frontal views shows that the level of the sphincteric mode of closure is the same for the experimental group as for normal adults. It is the difference in the anatomy of children and adults that accounts for what initially appeared to be a difference in closure mechanism. Thus, as the child grows and the adenoids atrophy, velaradenoidal closure is replaced by velar-pharyngeal closure.

The presence during speech of a Passavant's Ridge in 33% of the subjects observed in this study would seem to suggest that the ridge is a compensatory mechanism enabling individuals who might otherwise be incompetent during speech to achieve closure. The 33% figure is similar to our previous observation of a 27% incidence of Passavant's Ridge in individuals with velopharyngeal incompetence (*18*). The development of the Passavant's Ridge as a compensatory mechanism was nicely demonstrated by a subject who was examined videofluoroscopically at the age of 11 and again four years later at the age of 15 following adenoid atrophy (Figure 5). At age 11 he exhibited velar-adenoidal closure in lateral view with no evidence of a Passavant's Ridge, while at age 15 he utilized an active Passavant's Ridge during speech to achieve velopharyngeal closure.

Statistical analysis of the seven measures from frontal view and the single measure from lateral view indicated that in no instance was a statistically significant difference found for medial excursion of the LAPW and velar height between /p/, /t/, /k/, and /s/ phonemes at the .05 level of significance. Thus,

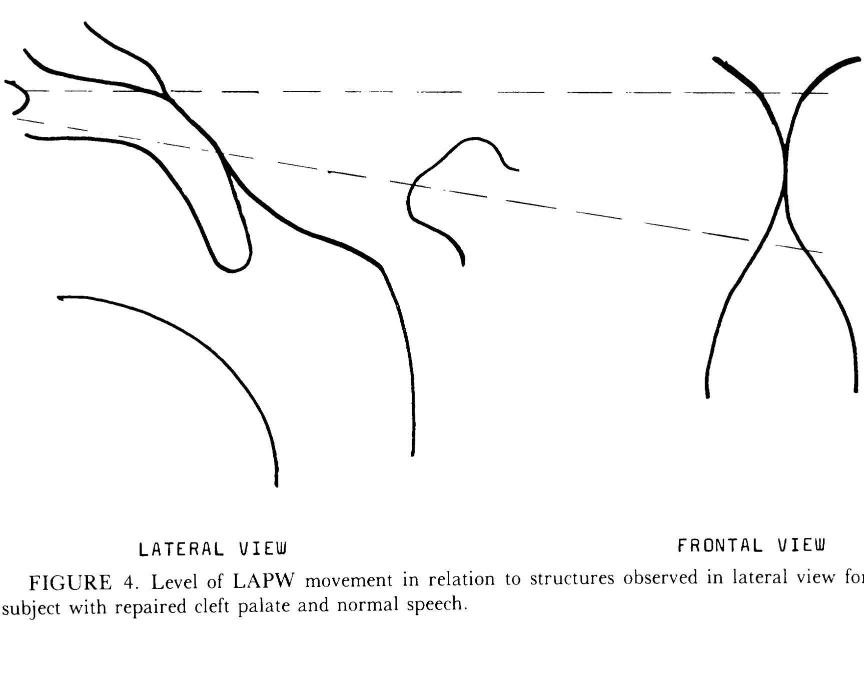

FIGURE 4. Level of LAPW movement in relation to structures observed in lateral view for subject with repaired cleft palate and normal speech.

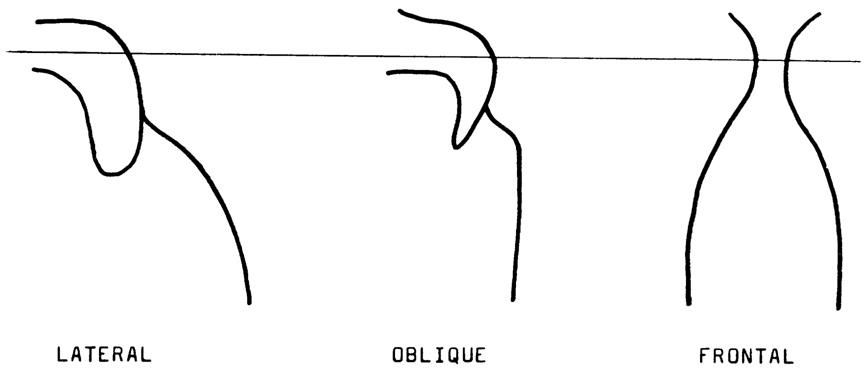

FIGURE 5. Lateral, oblique, and frontal views of subject with repaired cleft palate and normal speech showing synchronization of the level of velar and pharyngeal wall movement.

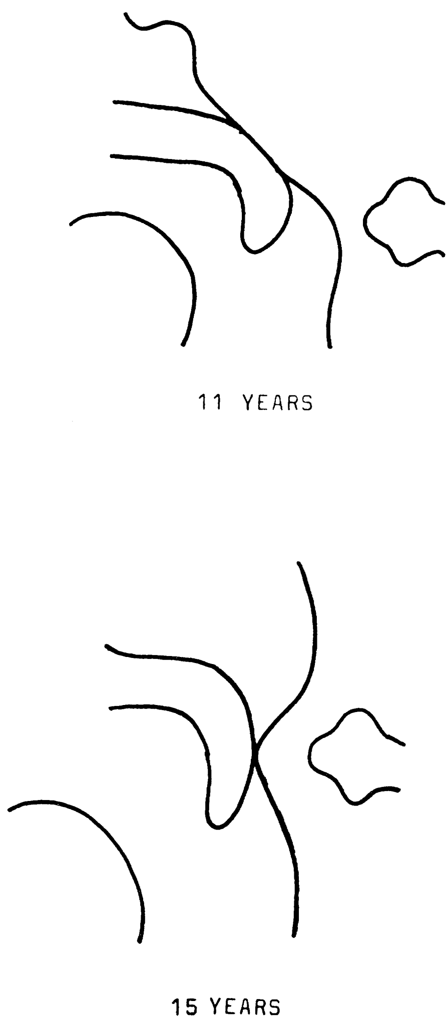

FIGURE 6. Lateral view of subject with repaired cleft palate and normal speech before and after adenoid atrophy (11 and 15 years).

the velopharyngeal closure pattern was consistent across these four consonants in connected speech.

Summary and Conclusion

Thirty subjects with repaired palatal clefts and normal speech ranging in age from 2 to 12 years were examined in multiple videofluoroscopic projections in order to assess velopharyngeal closure in three dimensions. The following points became evident from the results of this study:

1. All 30 subjects exhibited contact between the superior border of the velum and the adenoid mass in the nasopharynx. Often, a sharp levator eminance was not formed due to the small space between the velum at rest and the adenoids. Thus, there was little room for the velum to elevate.
2. All 30 subjects showed good localized medial movement of the LAPW at the approximate plane of the hard palate.
3. 10 out of 30 subjects, 33%, had a Passavant's Ridge during speech. All 10 of these subjects utilized the ridge as a point of closure, as well as the adenoids.
4. The observed patterns of closure were consistent across varied consonant utterances.
5. The mechanism of velopharyngel closure in this group of subjects is essentially the same as for normal adult speakers and differs only anatomically due to a lack of verticle head growth in children. Thus, in spite of the presence of adenoids and the lack of verticle head development, the basic sphincteric mechanism of velopharyngeal closure is utilized in these subjects.

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