Reliability of The Nasopharyngeal Fiberscope (NPF) for Assessing Velopharyngeal Function

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Simultaneous side-view nasopharyngeal fiberscopic (NPF) and lateral cinefluoroscopic (cine) recordings were taken for two normal subjects to determine the stability of NPF placement for the study of velopharyngeal function, and the reliability and validity of NPF findings. The results indicate that the NPF was highly stable during the several velopharyngeal activities examined, the NPF tip maintaining a relatively constant relationship within the vertebral complex. Therefore, it seems likely that similar NPF views are obtained on different occasions with a subject. The findings also indicate that measurements can be made from NPF still photos for several aspects of the velopharyngeal mechanism. However, measurements of the left lateral wall movement were not reliable. Measurement of velar movement from NPF correlated well with cine measures of velar movement, indicating validity of that NPF measure.

This is an initial report about the use of the nasopharyngeal fiberscope (NPF) for assessing velopharyngeal function. One kind of NPF instrumentation is considered, as well as stability and positioning of NPF with that technique. Also reported are findings on the reliability and validity of measurements taken from NPF photographs.

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Background of the problem

Specialists in cleft palate and related disorders have been interested for some fifty years in the development of methodology for observing velopharyngeal function during speech. A variety of methods has been developed, but primarily used are radiographic techniques for visualizing structural relationships in the velopharynx, and air pressure-flow techniques from which inferences about these relationships can be made.

Both techniques have advantages and disadvantages. The benefits of observing structural relationships are clear, but the general concern about radiation levels, even very low dosages, has added impetus to the search for nonradiographic methods for accomplishing that purpose. An additional need, unmet by some radiographic techniques, is to obtain information about mesial movement of the lateral pharyngeal walls as they contribute to velopharyngeal function.

For several reasons, the general technique of endoscopy is attractive as a means for

observing the velopharyngeal mechanism. Except for the need for surface anesthesia in some subjects, the technique is noninvasive and not harmful in the hands of an experienced examiner. Endoscopic views can provide information in the transverse plane and so may be useful in learning about lateral wall movement. Placement can be maintained for a period of time and so extended observation is possible. Both speech and nonspeech activities can be observed. Finally, endoscopic views can be recorded photographically for future evaluation.

Two types of endoscopic techniques have been used for this purpose. Nasal endoscopic methods for observing velopharyngeal function have been used by Pigott and his associates (1969a, 1969b, and 1974). Oral endoscopy has been described by Taub (1966), Willis and Stutz (1972), and Shelton, Paesani, McClelland and Bradfield (1975). Nasal endoscopy has the advantage that scope placement does not interfere with speech production. However, insertion of the scope into the nasal cavity is usually more uncomfortable than in the oral cavity. Both kinds of endoscopes are rigid and, of necessity, somewhat large in diameter. In some instruments, the excessive heat generated by the light source is also a hindrance to common use.

The advent of fiberoptics offers new opportunities for endoscopy of the velopharyngeal mechanism. The diameter of the fiberoptic bundle is smaller than that of conventional endoscopes and insertion is somewhat easier. The heat problem is virtually eliminated because of the use of a "cold" light source. Several authors have provided descriptions of the application of fiberoptics to endoscopy for study of velopharyngeal function for speech (Sawashima and Ushijima 1971; Solnick, McCall, and Barnes 1973; Matsuya, Miyazaki and Yamaoka 1974; Zwitman, Gyepes, and Ward 1976; Matsuya, Yamaoka and Miyazaki, 1979; Bell-Berti 1981; Croft, Shprintzen, and Rakoff 1981; and Ibuki, Tamaki, Matsuya, and Miyazaki 1981). Some preliminary findings have been reported by all these authors.

There are some problems, however, in using endoscopy for assessing velopharyngeal function that have not been addressed. One is the question of whether there is such variance from one placement to another that different views of the mechanism are obtained. That is a particular concern with the fiberoptic technique, which is highly flexible. The flexibility is a great advantage for many purposes but it also means that the examiner has only limited control over the location of the tip of the instrument where the lens is located. Another important question is whether viewers can be trained to evaluate the findings in a reliable manner.

The purpose of this paper is to describe some instrumentation and a procedure for using the nasopharyngeal fiberscope (NPF) for examining the velopharyngeal mechanism and to provide some information about the stability of placement of the fiberscope. Further, some data will be reported about reliability and validity of NPF findings when the NPF observations are recorded by still photography and analyzed by measurement technique. Normal subjects were used to reduce the amount of heterogeneity of velopharyngeal function, and because this is a preliminary study.

Procedures

INSTRUMENTATION AND OBSERVATION TECHNIQUE. The nasopharyngeal fiberscope used in this study was the NPF type S3[1] (Figure 1) with a lateral objective lens with an optical angle of 52 degrees. The outside diameter of the fiberscope is 3.4 mm, and the fiberscope is 770 mm in length. Illumination was provided by a cold light supply (Olympus CLK 3). Because of our need for photographic records of the NPF views for future study the fiberscope was coupled to a 35 mm still camera (Olympus OM-2). The camera was mounted on a heavy elevator tripod (Leica #98327) with the use of a large ball adapter (Leitz-Wetzler #14168) which allows 180 degree rotation. The rotation was required so that the camera position could accommodate necessary positioning of the tip of the fiberscope in the nasopharynx.

The subject was seated in a dental chair. The head was positioned and immobilized using a standard cephalostat. Several minutes after application of a spray surface anesthesia (4% Lidocaine sodium), the nasopharyngeal fiberscope was inserted through the right nostril (the right nostril was arbitrarily chosen). Insertion was usually accomplished without difficulty.

Within certain limits the NPF can be used to obtain a variety of views of the velopharynx. For example, the objective might be to assess velar elevation specifically (Bell-Berti, 1981). Because we were interested in the contributions of the velum and the pharyngeal walls to velopharyngeal function, the fiberscope was positioned so that all four boundaries of the mechanism (the velum, the posterior pharyngeal wall, and the two lateral pharyngeal walls) were visible in a single view. Repeated insertions were sometimes necessary so that this criterion could be met. Some additional adjustment of the position of the NPF tip was made possible by an adjustment mechanism located near the eye-piece. This mechanism permitted "bending" (in the inferior-superior direction) of the NPF tip to a limited extent, as well as fixation of the tip after proper positioning of the tip is achieved.

After the desired NPF view was obtained, the fiberscope was secured immediately anterior to the nostril with a clamp which was attached to the cephalostat. The stabilization was necessary to prevent rotation of the NPF or its displacement in the antero-posterior direction during the examination.

For some purposes, the examiner may want to change the position of the NPF tip. However, we were interested in maintaining a stable position of the NPF tip so that we could estimate the extent to which there was measurement error in the technique.

The positioning of the NPF tip was examined through lateral cinefluoroscopy prior to data collection to determine whether the NPF

FIGURE 1. The nasopharyngeal fiberscope, with lateral lens, Type S3, manufactured by the Olympus Optical Co., Tokyo.

interfered with velar excursion. In a few instances, the velum seemed to touch the NPF; when that happened, the tip was re-positioned so that there was no observed interference with the velum.

DATA COLLECTION. Two normal adult English speakers were used as subjects, one male (50 yrs) and one female (24 yrs). The fiberscope was positioned in the manner described above with the camera accessory. Simultaneous NPF film and cinefluoroscopic films were made while the subjects performed inspiration, soft blowing, and six sustained phonemes (/i/, /a/, /u/, /s/, /θ/, /n/). Sustained activities were chosen to facilitate the photography. The cinefluoroscopic procedure has been described earlier by Moll (1960) and Kent and Moll (1969). The procedure yields films at 24 fps.

These simultaneous data were taken twice for each of the two subjects at an interval of one week. Estimated dosage of x-ray was less than 1.2 rad per subject. The NPF photographs were taken during the presumed steady-state of each activity. The shutter click of the camera was sufficiently loud to be recorded on the sound track of the cine film, and was later used in data analysis to identify simultaneous cine film frames for each NPF photograph.

All NPF photographs and cine film frames were traced and measured independently by the two senior authors. NPF films were processed into slides and were analyzed as follows. For each subject, the transparency for the initial inspiration was enlarged to dimensions of 170 mm × 170 mm, projected to a tinted glass, and traced on tracing paper. Three black dots on the image, the result of three broken optical fibers in the fiberscope, were also traced. Similar tracings were made for each of the seven other activities (blowing, /n/, /i/, /a/, /u/, /s/, /θ/). The result was eight tracings for each subject for each session. The tracings of each of these seven activities were superimposed on the tracing of inspiration using the 3 black dots to assure accurate alignment. Measurements were made relative to inspiration.

Landmarks and measurements for the analysis of the NPF films are shown in Figure 2, left. X-Y coordinates were drawn to intersect at the posterior-most margin of the soft palate during the inspiration condition and were used as the reference for all measures. Sometimes the Y coordinate was near midline, but frequently it was displaced to the right side since the fiberscope was inserted through the right nostril. Because of this apparent displacement, the Y axis was considered a pseudomidline. As shown in Figure 2, five measurements were made: maximum velar movement for inspiration position along the Y axis (NVMp); maximum diameter of the velar port in the A-P direction (NVP); and mesial movement of the right lateral wall (RL) and left lateral wall (LL) toward the Y axis.

Measurements from the cine films are also shown in Figure 2 (right): maximum velar movement (CVM); minimum distance between NPF tip and the nasal surface of the soft palate (MD); and velar displacement parallel to the long axis of the fiberscope (PD). The CVM measure is similar to a comparable measurement used by Moll and Daniloff (1971) and Iglesias, Kuehn, and Morris (1980). The other two were developed specifically for this study.

Results

Not all NPR films were useable in the analysis. Some were unaccountably over or underexposed. The major problem was glare. If we saw glare through the eyepiece before attaching the camera, readjustments were made. In some instances, however, no glare was observed through the eyepiece during recording but did appear in the transparency used for the analysis. As a consequence, it was impossible to obtain some measures from some of the transparencies and, therefore, some of the analyses were based on a smaller number of observations.

STABILITY OF NPF PLACEMENT. Twenty cine frames were randomly selected from the films collected for each subject on each experimental occasion. Each frame was projected to life size on a tinted glass with an X-Y template. Three reference points were identified on each of the 20 film frames: the NPF tip and two skeletal landmarks, incisal tip of the incisor, and tubercule of Atlas. The stability of NPF placement was examined by comparing the linear relationship between the NPF tip and the two skeletal landmarks during the experiment. X-Y coordinates for each reference

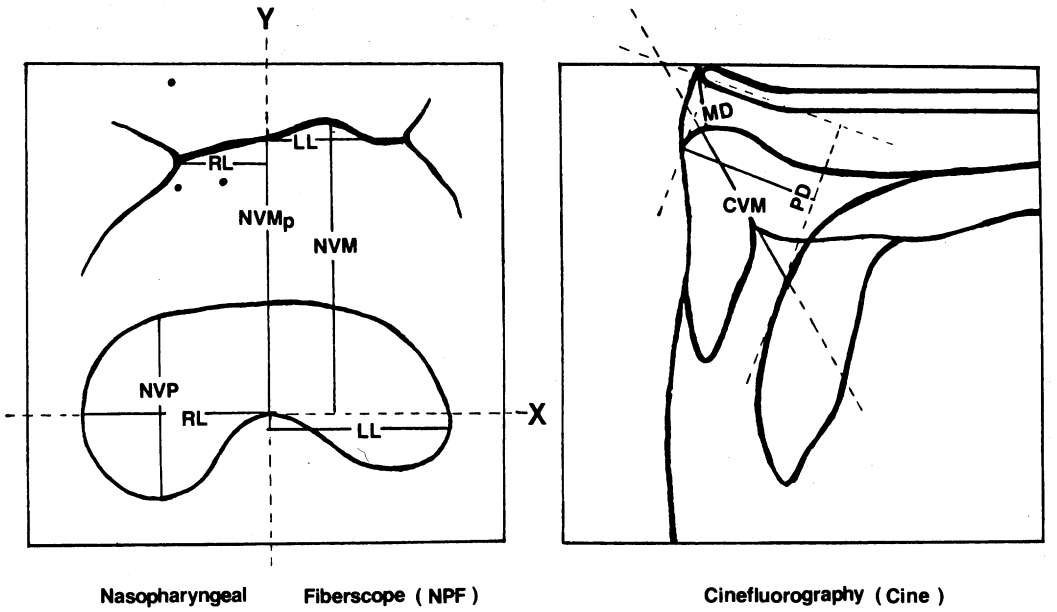

FIGURE 2. Landmarks and measurements made from NPF and cine films. Definitions are provided in text.

point in each of the 20 frames were identified for each experimental session. The pair of X-Y coordinates for the three points determined on the first randomly-selected frame was subtracted from the pair of X-Y coordinates determined on the second randomly selected, frame. This subtraction procedure was performed on all subsequent, randomly selected frames. As a result, nineteen values were obtained for the X-Y coordinates for each reference point. If there was no displacement of the three reference points among any film frames, all of the subtracted values would sum to zero. Mean differences were computed and t-tests were used to determine whether each mean differed from zero. None of the means was statistically different from zero (at the .05 level), indicating that the NPF tip was stable in the sagittal plane.

CONSISTENCY OF PLACEMENT. Geometric analysis was performed to determine the relationship of the NPF tip to the skeletal landmarks. The linear dimensions and angles formulated by these three points were computed on the twenty pairs of X-Y coordinates from each experimental session for each subject. None of the differences between the two experimental sessions, within subjects, was statistically significant (at the .05 level). The results suggest that the NPF tip and craniovertebral complex maintain a sufficiently constant relationship throughout the data collection process.

TABLE 1. Correlation Coefficients between Measurements Made Independently by Two Judges for Various NPF and Cine Measures

	Measure	*N*	*r*
	NVM	64	0.98
	NVM_p	63	0.94
NPF[1]	RL	40	0.86
	LL	33	0.09
	NVP	64	0.91
	CVM	40	0.95
CINE[2]	MD	40	0.97
	PD	40	0.88

[1] Maximum number of NPF observations is 64 (8 activities by a total of 8 sessions); only partial data available for some measurements.

[2] Maximum number of cine observations is 40 (8 activities by a total of 5 sessions).

RELIABILITY OF NPF MEASUREMENTS. To estimate the reliability of the tracing and measuring procedures, NPF and cine measurements made by the two senior authors were compared. The findings presented in Table 1 indicate high agreement between the two sets of measurements for all measures

except mesial movement of left lateral wall (LL).

To estimate temporal reliability of the NPF and cine measures, correlation coefficients were computed for measurements from several sessions (Table 2). Two kinds of comparisons are reported in Table 2 for each subject: a comparison based on the first two sessions, and a comparison based on all the three sessions (recall that the third session for subject 1 and the second and third sessions for subject 2 included only NPF data). The data indicate good agreement among data collected on different sessions, except for measure LL (left lateral wall movement).

TABLE 2. Correlation Coefficients between Measurements Made by Two Judges (A and B) on Two and Three Occasions for Various NPF and Cine Measures

Measurement	*Judge*	*Judge*
Subject #1		
Session 1 and 2 (linear regression)		
NVM	0.98	0.99
NVMp	0.97	0.99
RL	0.86	0.92
LL	0.45	0.21
CVM	0.97	0.93
MD	0.95	0.99
PD	0.82	0.83
Session 1, 2 and 3 (multilinear regression)		
NVM	0.98	0.88
NVMp	0.72	0.98
RL	0.82	0.92
Subject #2		
Session 1 and 2 (linear regression)		
NVM	0.95	0.96
NVMp	0.96	0.95
Session 1, 2 and 3 (multilinear regression)		
NVM	0.87	0.90
NVMp	0.88	0.88

VALIDITY OF NPF MEASURES. Comparisons were made between certain NPF and cine measures to estimate the validity of the NPF measures. Specifically, measurements of NPF velar movement along the pseudomidline (NVMp) and at greatest velar displacement (NVM) were correlated with corresponding cine measures of velar movement (CVM), distance between NPF tip and soft palate (MD), and velar displacement parallel to the long axis of the fiberscope (PD). Correlation coefficients were computed for measurements obtained by each of the two tracers and for each individual subject (Table 3). Correlation coefficients for the second session were also available for one subject. The coefficients are quite high, ranging from .82 to .99.

As a further examination of whether NPF findings agree with cine findings, NPF and cine data were normalized for direct comparison and the z-transformations plotted for the two data sets in Figure 3. As the figure shows, the two data sets, in z-scores, are highly similar. Greatest difference is for the vowels /a/ and /i/.

Discussion

The purpose of this study was to provide information about the reliability and validity of one kind of nasopharyngeal fiberscopic procedure to estimate velopharyngeal function.

TABLE 3. Correlation Coefficients between NPF Measures NVM and NVMp and Three Cine Measures of Velar Movement, for Measurements from Judges A and B

Session #1	*NVM versus*			*NVMp versus*		
	CVM	*MD*	*PD*	*CVM*	*MD*	*PD*
Subject 1 (A)	0.99	−0.98	0.91	0.97	−0.96	0.91
(n = 8) (B)	0.92	−0.97	0.82	0.92	−0.97	0.90
Subject 2 (A)	0.96	−0.96	0.89	0.96	−0.94	0.87
(n = 8) (B)	0.93	−0.93	0.95	0.90	−0.90	0.92
Subject 3 (A)	0.98	−0.97	0.93	0.97	−0.96	0.91
(n = 8) (B)	0.87	−0.98	0.96	0.89	−0.99	0.97
Subject 4 (A)	0.98	−0.89	0.91	0.86	−0.86	0.88
(n = 8) (B)	0.89	−0.94	0.87	0.91	−0.95	0.89
Session #2						
Subject 1 (A)	0.99	−0.99	0.84	0.99	−0.98	0.99
(n = 8) (B)	0.96	−0.96	0.95	0.98	−0.99	0.96

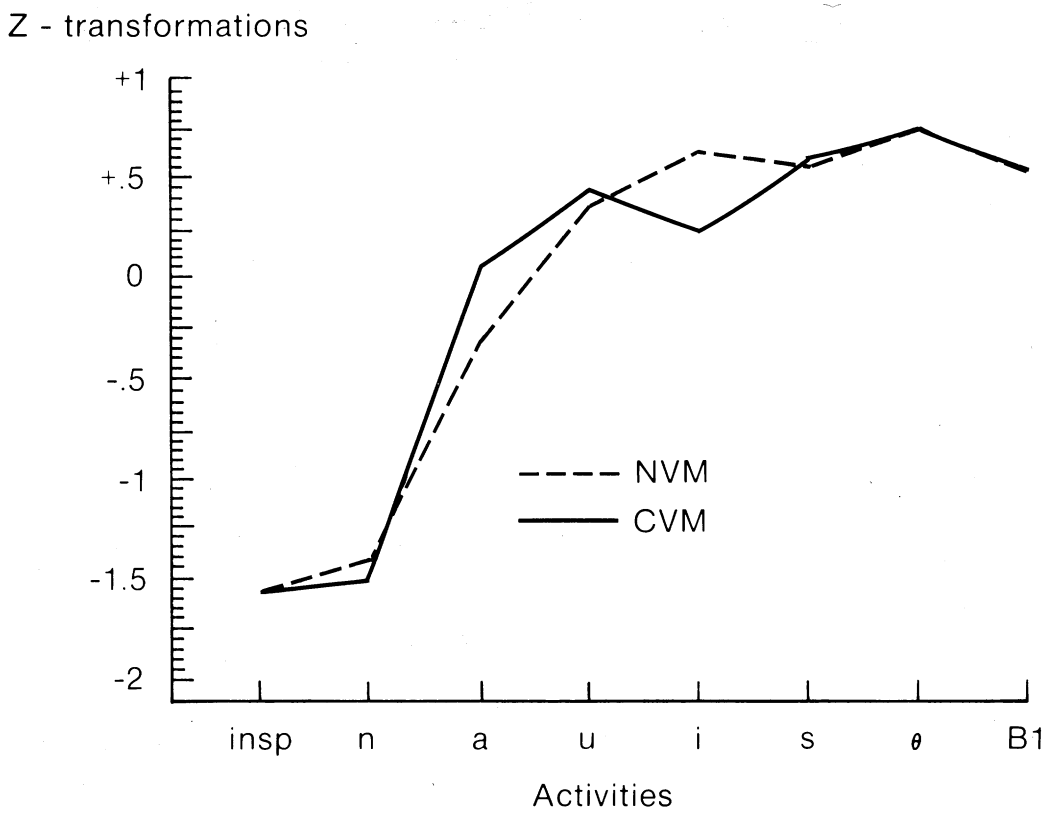

FIGURE 3. Z-transformations for NVM and CVM for eight tasks (inspiration, /n/, /a/, /u/, /i/, /s/, /o/, and blowing).

Specifically we found that with our pre-determined criteria the NPF tip was placed in approximately the same position in the nasopharynx from one examination to the next, and that positioning was relatively stable during the examination. The findings indicate also that a trace-and-measure procedure can be used on NPF still photographs that gives reliable data. Finally these data indicate that NPF data about velar movement agree rather well with another measure of velar movement, that taken from lateral x-ray films. In a future report we intend to investigate the reliability of a clinical judgment method of evaluating NPF findings, since the trace-and-measure procedure is too laborious to use in anything but research studies.

We consider these to be important findings, since as far as we can determine, no other information about the reliability of the NPF procedure or analysis of NPF data has been published. However, they clearly are preliminary findings and need to be extended by other investigations. One obvious need is to describe reliability of the NPF procedure with cleft palate patients. Another need is to determine whether there are differences in observations depending on whether a side lens is used (such as was used here) or an end-lens, such as is typically used in NPF procedures for viewing the larynx.

In our opinion the question of whether NPF procedure gives reliable data about lateral wall movement is still unanswered. The findings reported here are ambiguous in that respect, and further investigation is needed. Presumably that is viewed by many as a great advantage of the NPF procedure, and so it is an important question to be considered in future studies.

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References

BELL-BERTI, F., Velopharyngeal function: A spatial-temporal model. In Norman J. Lass (ed.), Speech and Language, Advances in Basic Research and Practice, Vol IV Academic Press, New York, 1980.

CROFT, C. R., SHPRINTZEN, R. J., and RAKOFF, S. J., Patterns of velopharyngeal valving in normal and cleft palate subjects: A multi-view videofluoroscopic and nasendoscopic study. *Laryngoscope, 91:* 265–271, 1981.

IBUKI, K., TAMAKI, H., MATSUYA, T., and MIYAZAKI, T., Velopharyngeal closure in patients with facial paralysis: The fiberscopic examination of the velopharyngeal movements, *Cleft Palate J., 18:* 100–109, 1981.

IGLESIAS, A., KUEHN, D. P., and MORRIS, H. L., Simultaneous assessment of pharyngeal wall and velar displacement for selected speech sounds. *J. Speech Hear. Res., 23:* 429–446, 1980.

MATSUYA, T., MIYAZAKI, T., and YAMAOKA, M., Fiberscopic examination of velopharyngeal closure in normal individuals. *Cleft Palate J., 11:* 286–291, 1974.

MATSUYA, T., YAMAOKA, M., and MIYAZAKI, T., A fiberscopic study of velopharyngeal closure in patients with operated cleft palates. *Plast. Reconstr. Surg., 63:* 497–500, 1979.

MOLL, K. L., Cinefluorographic technique in speech research. *J. Speech Hear. Res., 3:* 227–241, 1960.

MOLL, K. L., and DANILOFF, R. G., Investigation of the timing of velar movements during speech, *J. Acoust. Soc. Am., 50:* 678–684, 1971.

PIGOTT, R. W., The nasoendoscopic appearance of the normal palatopharyngeal valve, *Plast. Reconstr. Surg., 43:* 19–24, 1969a.

PIGOTT, R. W., BENSEN, J. F., and WHITE, F. D., Nasoendoscopy in the diagnosis of velopharyngeal incompetence, *Plast. Reconstr. Surg., 43:* 141–147, 1969b.

PIGOTT, R. W., The results of nasopharyngoscopic assessment of pharyngoplasty, *Scand. J. Plast. Reconstr. Surg., 8:* 148–152, 1974.

SAWASHIMA, M., and USHIJIMA, T., Use of the fiberscope in speech research, *Annual Bulletin* (Research Institute of Logopedics and Phoniatrics, University of Tokyo), *5:* 25–34, 1971.

SHELTON, R. L., PAESANI, A., MCCLELLAND, K. D., and BRADFIELD. S. S., Panendoscopic feedback in the study of voluntary velopharyngeal movements. *J. Speech Hear. Dis., 40:* 232–244, 1975.

SKOLNICK, M. L., MCCALL, G. N., and BARNES, M., The spinteric mechanism of velopharyngeal closure. *Cleft Palate J., 10:* 286–305, 1973.

TAUB, S., The Taub oral panendoscope; a new technique, *Cleft Palate J., 3:* 328–246, 1966.

WILLIS, C. R., and STUTZ, M. L., The clinical use of the Taub oral panendoscope in the observation of velopharyngeal function. *J. Speech Hear. Dis., 37:* 495–502, 1972.

ZWITMAN, D. M., GYEPES, M. T., and WARD, P. M., Assessment of velar and lateral wall movement by oral telescope and radioscopic examination in patients with velopharyngeal inadequacy and normal subjects. *J. Speech Hear. Dis., 41:* 381–389, 1976.