Changes in Nasal Resonance Related to Differences in Location and Dimension of Speech Bulbs

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Previously we have described the placement of the pharyngeal section of the prosthetic speech aid (*3*, *9*, *10*). The opinion of several investigators has been that placement of the pharyngeal section in the approximate area where 'normal' velopharyngeal closure takes place will produce optimal voice quality (*1*, *10*). These impressions were apparently based on clinical rather than research observations. This study was designed to investigate the possible effects on voice quality of placement of the speech bulb (or pharyngeal section) at three selected positions.

Equipment

The two radiographic instruments employed in this study were: a cineradiographic system with a nine-inch Keleket image intensifier tube and Wehmer Roentgenographic Cephalometer with two x-ray tubes for anteroposterior and lateral registration (*7*, *11*).

An Ampex SP-300 four-channel tape recorder simultaneously recorded all speech samples on tape as the subject was recorded by the cineradiographic system. These taped speech samples were then analyzed by a Kay Electric Sona-Graph (Figure 1). The Sona-Graph is an instrument which analyzes a complex signal as a function of both frequency and time. The resultant portrayal, known as a sonagram, displays frequency along the vertical axis, time along the horizontal axis, and intensity by the darkness of the pattern. This type of automatic analysis is very useful in giving a clear and permanent picture of complex signals that vary with time. The signal spectrum is scanned by either a 45-cycle or 300-cycle band-pass filter. The output of the analyzing filter is then recorded on dry facsimile paper that is fastened around a drum rotating in synchronization with the magnetic recording disc.

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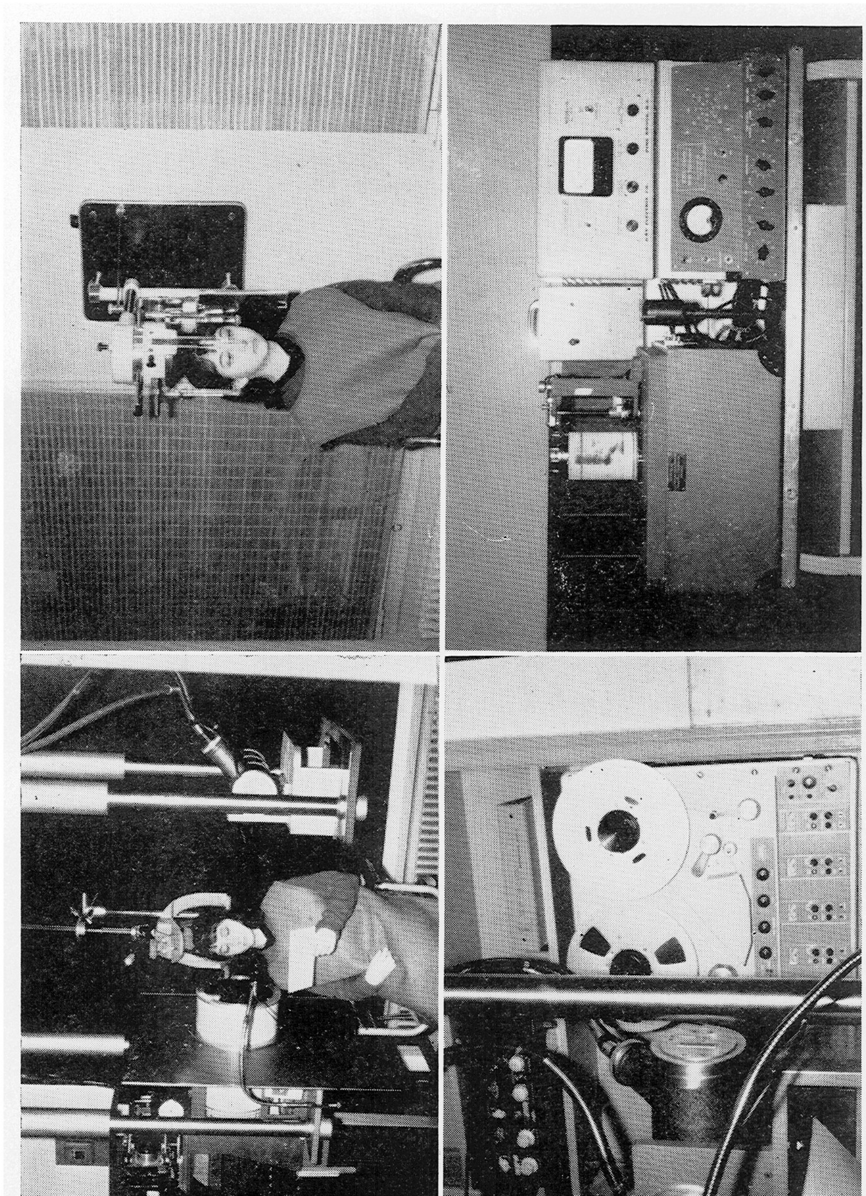

FIGURE 1. Upper left: cineradiographic system. Upper right: roentgenographic cephalometer. Lower left Ampex SP-30 4-channel tape recorder synchronized with cineradiographic unit. Lower right: sound spectographic with scale magnifier and amplitude display.

A second type of analysis, known as a section, is displayed at the upper half of the sonagram. This auxiliary presentation with the addition of the section micrometer provides, at any pre-selected point in time, portrayal of amplitude in the horizontal direction versus frequency in the vertical direction. The display is made on a uniform decible scale with a range of 35 dB.

A third type of portrayal, providing a permanent record of the variation of average amplitude versus time, was obtained by using the amplitude display unit. This display, using an amplitude scale that is logarithmic over a 24 dB range, is produced on the top one and one-half inches of the sonagram.

The fourth type of analysis, scale magnification, is one in which any ten per cent portion of the vertical frequency scale is expanded by a factor of ten. With the built-in calibrator it is possible to obtain fine measurements of frequency changes (Figure 2).

SUBJECTS AND PROCEDURES. Ten young adults, three males and seven females, ranging from 15 to 20 years of age with nonoperated cleft palate, acceptable maxillo-mandibular dental relationships, and socially acceptable speech with prosthesis were selected for this study. Each patient's prosthetic speech appliance was constructed at the Lancaster Cleft Palate Clinic within the past three years. No subject had a hearing loss greater than 15 dB, bilaterally, for 500 through 4000 cps.

The position of the speech bulb was determined by using lateral headplate roentgenograms. Cineradiographic studies, employing image intensification and sound-on-film recording, were made to visualize the relationship of the oral pharyngeal mechanism to the speech bulb in varied positions during the process of phonation and swallowing. Instances of displacement of the prosthesis caused by the oral pharyngeal musculature were eliminated before recording the speech.

A direct measurement of the inferior-superior and lateral dimensions of the bulb was made utilizing calipers. The lateral measurement was made at the most prominent point of the bulb. The inferior and superior surfaces of the bulb were parallel so that the bulb was uniformly thick. All measurements were made to the nearest 0.5 mm.

High fidelity tape recordings were made of the subject's speech pattern with each positional change of the speech bulb. The three positions were *high* (above posterior pharyngeal wall activity), *medium* (on posterior pharyngeal wall activity), and *low* (below posterior pharyngeal wall activity) (Figure 3).

All subjects were allowed an adjustment period of five weeks following each bulb placement. All observations (speech and radiographic) were repeated immediately after each bulb change. Speech samples were recorded one week after placement, three weeks after placement, and at the end of the adjustment period for comparative study.

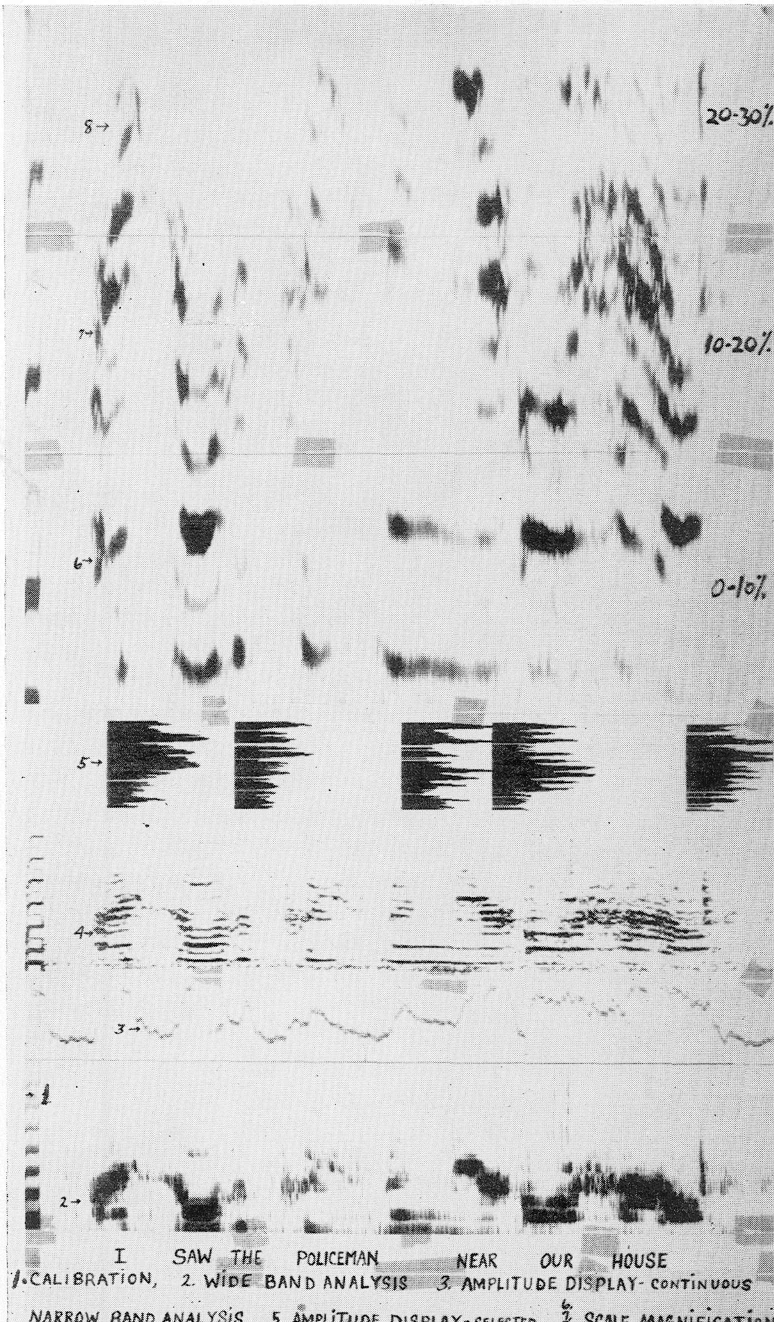

FIGURE 2. Series of sonagrams illustrating various portrayals obtained by sound spectrographic analyzer.

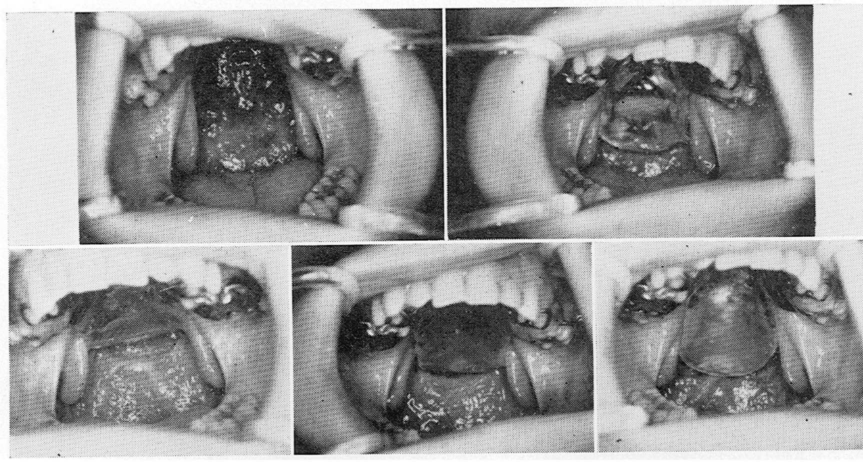

FIGURE 3. Upper left: male, age 17, unoperated cleft of soft and hard palate. Upper right: original prosthetic speech appliance in position. Lower left: speech bulb in high position. Lower center: speech bulb in medium position. Lower right: speech bulb in low position.

Landmarks for measurements are presented in Figure 4.

To determine the positional or dimensional changes of the pharyngeal section, we traced and superimposed the lateral cephalometric roentgenograms on the nasion sella and palatal plane line, and a composite tracing was made. From this tracing various linear measurements were recorded (Figure 4).

All subjects were trained so that they would be familiar with the material and apparatus. Each subject used his habitual pitch level at his conversational volume level during the phonation of selected vowels, syllables, and connected speech. The sequence was repeated twice.

Voice quality judgments were independently judged by two speech pathologists employing a five-point scale where the point *one* was considered hypernasal, *three* normal, and *five* hyponasal. Their correlation coefficient for agreement regarding judgment of quality was .93.

High quality disc recordings cut on a Presto K-11 recorder and sonagrams of the vowels /ɑ/, /æ/, /i/, and /u/ and selected samples of continuous speech produced by the Kay Electric Sound Spectrographic Analyzer were also used in judging quality disturbances. The McKesson Scott Vital Capacity Apparatus was used to measure air loss through the nasal passageways following complete expulsion of air with the nostrils occluded and unoccluded.

The judges were not familiar with the scrambled pattern the prosthodontist selected for positioning the speech bulb. The speech recording of the bulb in various positions following the adjustment period was utilized for analysis and judgment ratings.

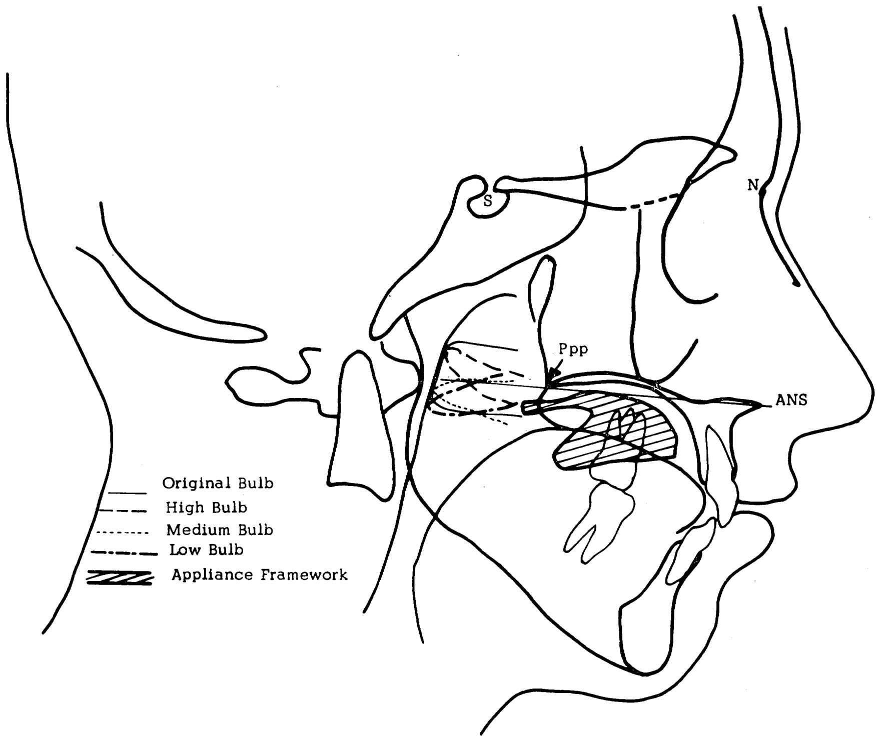

FIGURE 4. Superimposed tracing of the original and various experimental speech bulbs in position. The palatal plane was used as a plane of reference. The posterior nasal spine (PNS), absent in cleft palate subjects, is called posterior palatal point (Ppp) to represent the most posterior point of the remnants of the palatal shelves as shown in the lateral cephalometric x-ray film.

Results

Positional Changes. For each subject the sonagram which was judged to show increased intensity and appropriate location of formant frequencies was selected as representing the 'best' voice quality. In comparing other sonagrams with the standard, presence of the first and second vowel formants was used as criteria for judgment. In addition, wide band, narrow band, and sectional analysis of the vowels were used to aid in the comparison.

The sound spectrograms and the judgment of the listeners indicated that the recording immediately following each bulb change was similar to the previous recording regardless of where the bulb was positioned. In nine subjects, however, when the bulb was in the low position, the second and third recordings showed a definite omission or extreme reduction of the first and second formants, making it difficult to recognize the vowel frequency pattern.

TABLE 1. Measurements in millimeters for inferior-superior, lateral dimensions, and position in reference to the palatal plane for original and experimental bulbs.

Measures (in mm)	*Lateral Dimension*		*Reference to Palatal Plane*	
	Range	*Mean*	*Range*	*Mean*
Original Bulb	20 to 32	26.3	Highest Point	
			−10 to +10	+2
			Lowest Point	
			−24 to −3	−12
Bulb High	16 to 29	24.4	−3 to +9	+1
Bulb Medium	16 to 32	24.7	−10 to +3	−5.7
Bulb Low	17 to 32	24	−16 to −4	−13

\+ above palatal plane.
− below palatal plane.

With the speech bulb in the middle position the three spectrograms varied the least between immediate and final recordings following the adjustment period.

The second and third sonagrams with the bulb in the low position illustrated an increase in harmonic energy with a decrease in formant identification. The second and third sonagrams with the bulb in the high position indicated stronger formants than when the bulb was in the low position; however, the formants were not as strong as the corresponding sonagrams when the bulb was in the medium position.

The judges compared the speech recording of the speech bulb in various positions for each subject. They selected the medium position in seven subjects, the high position in three, and the low position in one subject as having the better voice quality judgment for the subject.

INFERIOR-SUPERIOR CHANGES. Nine of the subjects were selected for this part of the investigation. The inferior-superior dimension of the original speech bulb on these subjects varied from 13 mm to 19 mm with the mean of 13.09 mm. The size of the bulb was reduced inferiorly and/or superiorly to an average of 3 mm (Table 1).

There were essentially no differences in the sonagrams or judgments of quality for various bulb sizes. Apparently, then, as long as the speech bulb is properly placed and provided there is acceptable velopharyngeal closure, the inferior superior dimensional size does not have a perceived effect on nasal resonances.

LATERAL CHANGES. The lateral dimension of the bulb after each subsequent functional impression of the nasopharyngeal area did not change significantly with the positional changes of the speech bulb. This is contrary to our hypothesis that the lateral dimension of the nasopharynx is less at the level where the posterior and lateral pharyngeal wall activity takes place than above or below it (Table 1). Such was not the case.

Remarks

Sound spectrographic analysis has been employed by Curtis (*5*), Potter, Kopp, and Green (*13*), Thurman (*15*), Kelly (*8*), Smith (*14*), Cotton (*4*), and Dickson (*6*). Each investigator attempted to identify a reinforcement area associated with nasalized vowels. In this study identification of such a reinforcement area varied from the 200–250 cycle range to the 1000 cycle range, from no location of a reinforcement area to a reported 'increase' in the higher harmonics of nasality. From the material analyzed by sectional amplitude and scale magnified displays, we found an inconsistency in frequency area reinforcement.

Our initial use of the sound spectrographic analysis was concerned with changes in vowel characteristics as the location of the speech bulb was altered. A more extensive study is suggested to review the formant changes through the use of scale magnification. The formant changes may not be totally related to nasal resonance. Nasality as perceived by the listener could be an acoustical phenomenon not related to nasal air flow or nasal resonance as suggested by West (*16*).

Although the findings indicated that the judges and the spectrograms were in agreement, we feel that long-term experience of the two speech pathologists who served as judges allowed them to make more critical judgments than most speech pathologists who are infrequently called upon to make listening judgments of voice quality changes concerned with prosthetic speech aids. The authors (*12*) view the Sona-Graph as an instrument of scientific research and as a clinical diagnostic-teaching aid when utilized with other clinical and research instrumentations.

Summary

Ten subjects with unoperated cleft of the soft and hard palate wearing a prosthetic speech aid were selected to study the effects of nasal resonances following the location and the changes of the speech bulb. The following conclusions summarize the investigation. a) Voice quality was judged as *best* when the speech bulb was positioned on the posterior pharyngeal and lateral pharyngeal wall activity. b) Inferior-superior dimension of speech bulb was reduced to a factor of one-fourth without apparent effect in the nasal resonance. As a consequence the weight of the bulb was reduced with the same factor. c) The lateral dimension of the bulb did not change significantly as the position varied. d) Sophisticated instrumentation (cineradiography, cephalometric roentgenography, sonagraph, pressure and flow apparatus) employed in diagnosis and research media is of limited value when used independently. The utilization of several pieces of such specialized instruments will offer a significant index of the patient's status.

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