A Cephalometric Radiographic Evaluation of Pharyngeal Flap Surgery for Correction of Palatopharyngeal Incompetence

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The accomplishment of good speech is the ultimate aim in the rehabilitation of an individual with any anatomic or physiologic abnormality of the palate. The primary goal in the treatment of palatopharyngeal incompetence is the creation of a mechanism which makes normal speech production possible.

A variety of surgical techniques has been used to correct inadequate palatopharyngeal valving. In recent years, the pharyngeal flap operation seems to have become the most popular secondary surgical technique for the improvement of inadequate and nasal speech resulting from palatopharyngeal incompetence. It has also been employed in combination with palatoplasty as a primary procedure (*3, 14*).

Many research studies concerned with pharyngeal flap techniques have been reported. These investigations have been concerned with the nature of the resulting palatopharyngeal mechanism, and the success of the flap procedure relative to speech results (*2, 7, 9, 10, 11, 13, 14*).

From the speech results reported, following pharyngeal flap surgery, it seems apparent that success is dependent upon a number of factors. These factors seem to be related to the age of the patient at the time of surgery; the surgical procedure used; the skill of the surgeon; and the criteria used to evaluate results. Nylen (*10*) presents, in table form, the speech results reported by nine authors after pharyngeal flap surgery. The results rated as "normal and/or fair" ranged from 62 to 100 per cent. Many reports (*3, 7, 8, 11, 13, 14, 22*) have shown that about 75 to 90 per cent of the

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pharyngeal flap operations provide mechanisms capable of adequate speech.

The pharyngeal flap procedure has proven to be of great value to many individuals with clefts of the palate and/or inadequate palatopharyngeal closure. However, the literature recognizes that in approximately 10 to 25 per cent of the cases, the pharyngeal flap does not provide the patient with a functionally adequate speech mechanism. This indicates the need to better define the pre-operative anatomic and functional relationships that lead to an adequate as well as inadequate speech mechanism.

Despite varied research efforts, objective anatomic and physiologic criteria have not yet been established to clarify the indications and contra-indications of the pharyngeal flap procedure. Skoog (*13*) stressed the importance of evaluating the anatomical pre-requisites prior to the pharyngeal flap procedure, and stated that "not until we can benefit from the experience gained in a thoroughly examined series will it be possible to define more clearly the indications and contra-indications of this procedure." With this in mind, a lateral cephalometric radiographic study was undertaken. Pre- and post-operative data were comparatively analyzed in an effort to identify and differentiate anatomic and physiologic features associated with the success and/or failure of pharyngeal flap surgery. Information of this nature could be of great diagnostic and prognostic value in planning treatment for those individuals exhibiting palatopharyngeal incompetence.

Procedure

SUBJECTS. The subjects for this study were obtained from the Eastman Dental Center, Rochester, New York, and the Center for Craniofacial Anomalies of the University of Illinois, Chicago, Illinois. The sample consisted of 60 subjects with various types of clefts of the lip and palate: 14 with submucous cleft palate; 20 with cleft palate only; 18 with unilateral cleft lip and palate; and eight with bilateral cleft lip and palate. The subjects ranged from six to 43 years of age with 85 per cent falling within the six to 18 year old category (Table 1). The surgical status of the subjects prior to the pharyngeal flap procedure consisted of 25 with no previous palatal surgery and 35 that had at least one previous surgical procedure for palate closure. All the patients had palatopharyngeal incompetence and nasal speech as judged by competent speech pathologists, and were adjudicated to require pharyngeal flap surgery. The majority of the operations was performed by two surgeons. A superiorly-based pharyngeal flap procedure was utilized in 56 of the patients. An inferiorly-based pharyngeal flap was utilized in four of the cases.

DATA COLLECTION. The x-ray equipment and filming method incorporated all the accepted principles of cephalometric roentgenography as developed by Broadbent (*1*). It should be mentioned that the longitudinal aspect of cephalometric data permits evaluation of the changes in the

TABLE 1. Distribution of cleft type and age for the 60 subjects.

Cleft Type		*Age*	
		Range	*Mean*
Submucous	14	7/2–33/8	13/0
Cleft Palate Only	20	6/1–43/6	15/4
Unilateral Cleft Lip and Palate	18	6/10–29/2	13/8
Bilateral Cleft Lip and Palate	8	6/11–23/5	11/5

anatomy and physiology of the nasopharyngeal complex and other structures involved in speech production, before and incident to the pharyngeal flap procedure.

The data collected in this study consisted primarily of lateral cephalometric radiographs taken of each subject shortly before pharyngeal flap surgery and approximately eight months afterwards. The radiographs were taken with the subjects at rest, and during sustained production of the /u/ and /s/ sounds. Those taken at rest were used to measure and evaluate the configuration, posture, location, and size of hard and soft tissue structures. Functional changes were determined by evaluating the cephalometric radiographs obtained during the sustained production of the /u/ and /s/ sounds.

Method of Analysis. The cephalometric landmarks and baselines are described and illustrated in Figure 1. The tracings were analyzed using a Cartesian coordinate system established by drawing the palatal plane to represent the x-axis, and projecting a perpendicular line to this plane through the pterygomaxillary fissure to represent the y-axis.

Twenty-six angular, linear, and/or area measurements were made from the cephalometric tracings. Linear measurements were made in millimeters along a line parallel to either the palatal plane (abscissa) or the pterygomaxillary plane (ordinate). Linear measurements were made within 0.5 millimeters, and the angular measurements were made within 0.5 degrees, which were considered within the bounds of experimental measuring error. The nasopharyngeal area was measured by a technique described by Tirk (*20*), using the Lasico Compensating Polar Planimeter No. 123A. The measurements used in this study are described and illustrated in Figures 2, 3, and 4.

Additional data was collected on each of the subjects by Joanne D. Subtelny, Ph.D., Eastman Dental Center, Rochester, New York. This data included intraoral air pressure and nasal airflow measures. A continuous speech passage was also recorded for scaled ratings of nasality, nasal emission, articulation, and intelligibility. Ratings of nasality and nasal emission indicated the voice quality before and after pharyngeal flap surgery. Nasality ratings were used to define success (non-nasal speech) and failure (nasal speech) of pharyngeal flap surgery, and was justified

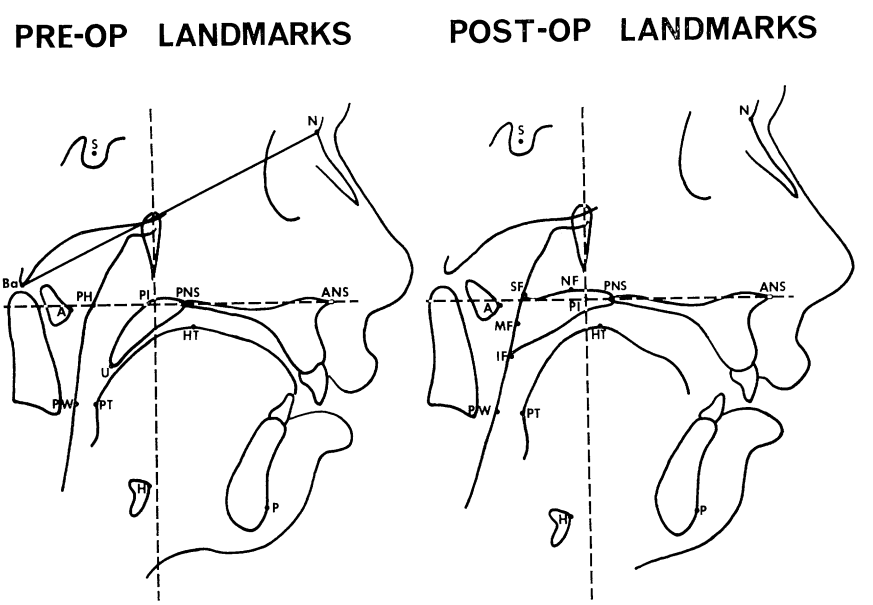

FIGURE 1. Pre-operative and post-operative cephalometric baselines and landmarks used in this study.

CONSTRUCTED BASELINES: PP, Palatal Plane; PTM (Pterygomaxillary Plane), perpendicular to the palatal plane extending through the pterygomaxillary fissure; N-BA (Nasion to Basion), a cranial baseline.

LANDMARKS: N, nasion; S, sella; P, pogonion; H, most anterosuperior point on body of hyoid bone; ANS, anterior nasal spine; PNS, most posterior margin of hard palate; A, most anteroposterior point of anterior tubercle of Atlas; PH, point where palatal plane extension intersects posterior pharyngeal wall; PW, a point on pharyngeal wall at the level of maximum constriction of either the tongue or soft palate; HT, high point of tongue relative to palatal plane; PT, posterior point of tongue relative to pharyngeal wall; U, tip of soft palate or uvula; PI, point of intersection of palatal plane and pterygomaxillary plane; V, point where palatal plane intersects nasal surface of soft palate.

ADDITIONAL POST-OPERATIVE LANDMARKS: SF, superior point of pharyngeal flap base as it blends into pharyngeal wall; IF, inferior point of pharyngeal flap base as it blends into pharyngeal wall; MF, midpoint of pharyngeal flap base along the pharyngeal wall; NF, midpoint of nasal surface of pharyneal flap.

by several factors. Nasality has been found to be significantly related to: palatopharyngeal opening (*4, 18*); nasal airflow; intraoral air pressure; articulation error; intelligibility of speech; and to nasal emission (*19*). On the basis of these findings, the judgement rating of nasality seemed the best single measure to appraise palatopharyngeal competence after flap surgery.

Two speech pathologists, specialized in the cleft palate area, rated nasality during continuous speech on a seven point scale, ranging from 1 (*denasality*) to 7 (*extreme hypernasality*). Ratings of 3 designated normal voice quality (*17*). Nasality ratings of 3 as well as ratings of 2 and 1 would indicate that the pharyngeal flap procedure has accomplished pala-

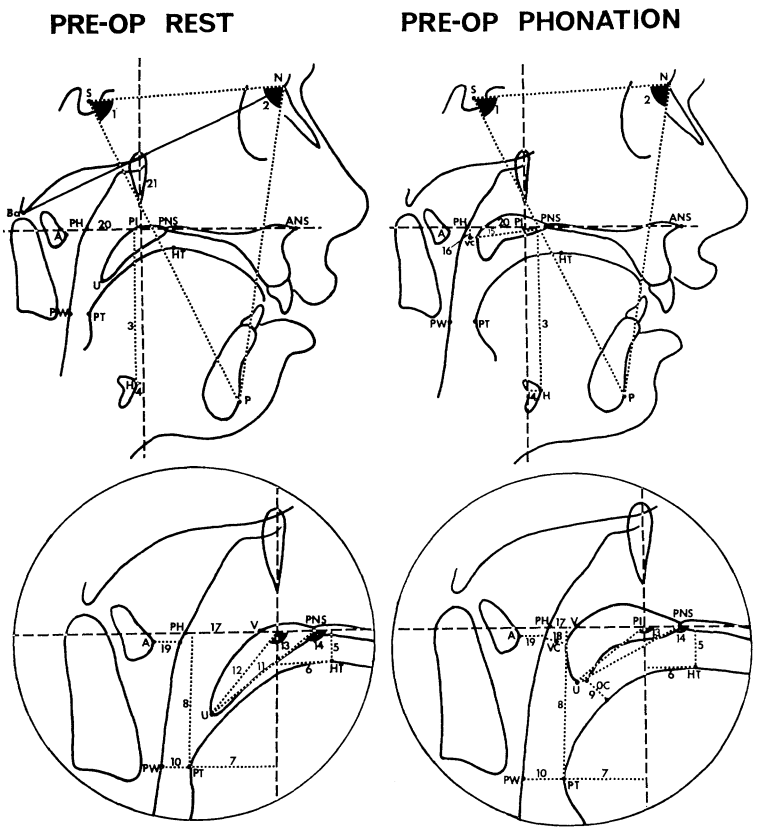

FIGURE 2. Pre-operative measurements made from cephalometric radiographs taken at rest and during sustained production of the /u/ and /s/ sounds.

POSITION OF MANDIBLE: Angle NSP, vertical position of chin relative to anterior cranial base; Angle SNP, anteroposterior position of chin to anterior cranial base.

POSITION OF HYOID BONE AND TONGUE: H-PP, vertical position of hyoid relative to palatal plane; H-PTM, anteroposterior position of hyoid relative to pterygomaxillary plane; HT-PP, vertical position of high point of tongue relative to palatal plane; HT-PTM, horizontal position of high point of tongue to pterygomaxillary plane; PT-PTM, anteroposterior position of posterior point of tongue relative to pterygomaxillary plane; PT-PP, vertical position of posterior point of tongue relative to palatal plane; Line OC, closest approximation of tongue to soft palate during phonation; PT-PW, closest approximation of posterior point of tongue to pharyngeal wall.

LENGTH AND POSITION OF SOFT PALATE: PNS-U, length of velum from posterior nasal spine to tip of uvula; PI-U, length of velum from pterygomaxillary intersect to tip of uvula; ANS-PI-U, angular position of velum in the nasopharynx relative to palatal plane; ANS-PNS-U, angular position of velum relative to palatal plane; VC-PNS-PH, angular position of midpoint of velopharyngeal constriction relative to palatal plane; VC-PP, vertical distance of midpoint of velopharyngeal constriction to palatal plane.

RESIDUAL VELOPHARYNGEAL OPENING: V-PH, distance from velum to pharyngeal wall at level of palatal plane; V-PW, closest approximation of velum to pharyngeal wall during phonation.

NASOPHARYNX AND POSTERIOR PHARYNGEAL WALL MOBILITY: A-PW, thickness of pharyngeal tissue overlaying the anterior tubercle of Atlas; PI-PH, depth of nasopharynx at level of palatal plane, it would also measure any anterior movement of the posterior pharyngeal wall during phonation; PI-Cranial Base, height of nasopharynx from palatal plane to cranial baseline (N-Ba) along the pterygomaxillary plane; Nasopharyngeal Area, See Figure 3.

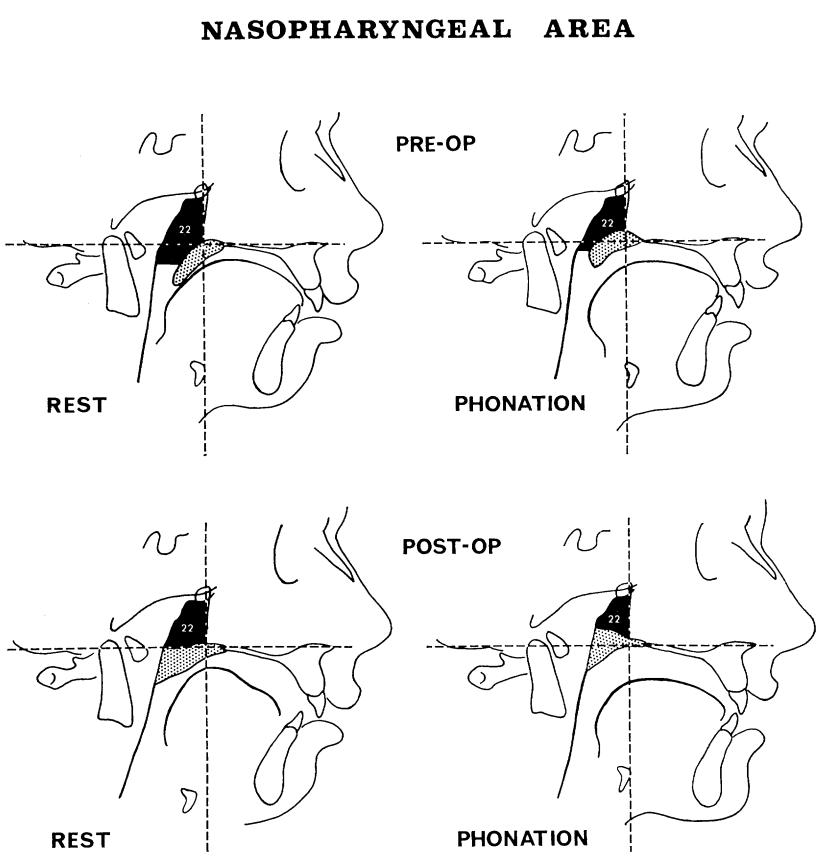

FIGURE 3. The black area (measure 22) represents the nasopharyngeal area measure. The stippled area in the top two pre-operative tracings represents the soft palate tissue. In the two bottom post-operative tracings the stippled area represents the pharyngeal flap tissue.

topharyngeal competence. On the basis of post-operative nasality ratings the subjects were then separated into successful and unsuccessful result groups. Subjects with post-operative nasality ratings of 3, 2, or 1 were assigned to the non-nasal group. Subjects with post-operative nasality ratings of 4 and above, indicating excessive nasality, were assigned to the nasal group. It should be mentioned that a patient with a nasality rating of 4 might still accomplish normal speech with adequate speech training. However, none of the patients in this study received speech training between the dates of pre- and post-operative study. Therefore, the effect of speech therapy was not a variable to be considered in the analysis of the data.

After the sample was divided into the two groups, the cephalometric data were comparatively analyzed with two considerations in mind: (1) to analyze the various anatomic relationships of the oral-nasal-pharyn-

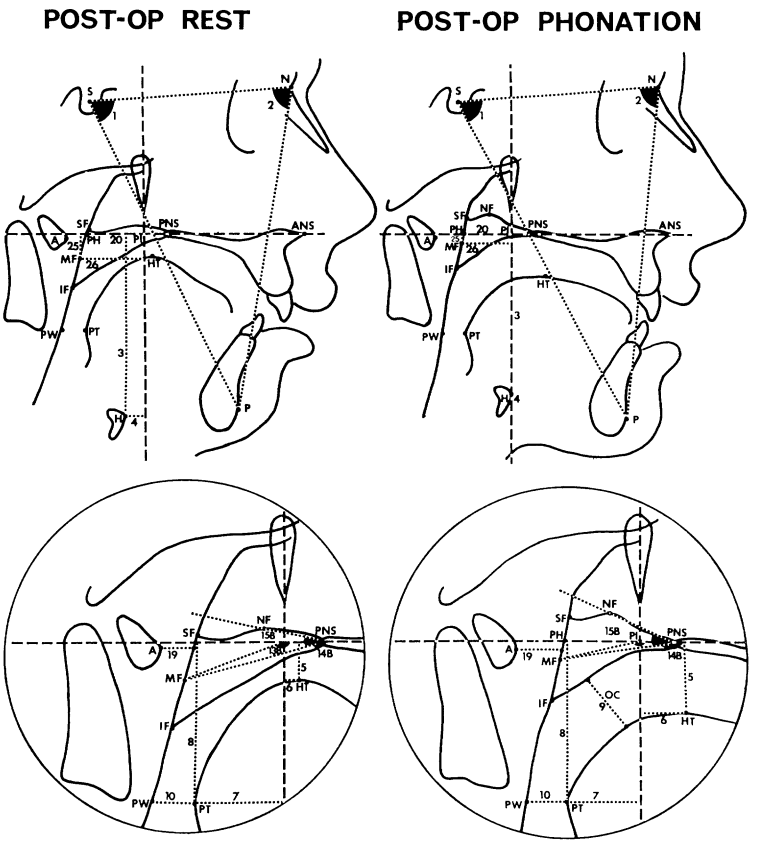

FIGURE 4. Additional post-operative measurements made from cephalometric radiographs taken at rest and during sustained production of the /u/ and /s/ sounds—subquent to the pharyngeal flap procedure.

POSITION OF PHARYNGEAL FLAP: ANS-PI, MF, angular position of midpoint of flap base in the nasopharynx relative to palatal plane; ANS-PNS-MF, angular position of midpoint of flap base relative to palatal plane; NF-PNS-MF, angular position of middle third of nasal surface of the pharyngeal flap relative to the midline of the flap (PNS-MF).

LENGTH AND POSITION OF PHARYNGEAL FLAP BASE: SF-IF, length of flap base attachment along the pharyngeal wall; MF-PP, vertical distance of midpoint of flap base to palatal plane; MF-PTM, horizontal distance of midpoint of flap base to pterygomaxillary plane.

geal complex at rest; and (2) to analyze the dynamic or functional aspects of these structures during production of the /u/ and /s/ sounds. More specifically, the measurements were made to differentiate the anatomic and functional relationships that could lead to an adequate as well as inadequate speech mechanism as a result of pharyngeal flap surgery.

Findings

EFFECT OF CLEFT TYPE, SURGICAL STATUS, PRE-OPERATIVE NASALITY RATINGS, AND AGE. The comparisons between the subjects who obtained

TABLE 2. Summary of the total sample, non-nasal group, and nasal group as classified by cleft type: Number of subjects in each cleft type, operated or unoperated surgical status before pharyngeal flap surgery. mean pre and post-operative nasality ratings, and mean age at the time of the pre-operative study.

Subjects	*Cleft Type*	*n*	*Surgical Status Before Flap*		*Mean Nasality Ratings*		*Mean Pre-Op Age*
			Op.	*Unop.*	*Pre*	*Post*	*Years/ Months*
Total Sample (n = 60)	SMC	14	0	14	6.07	3.29	13/0
	CP	20	10	10	6.00	3.10	15/4
	UCL & P	18	17	1	6.06	3.39	13/9
	BCL & P	8	8	0	6.13	3.63	11/7
	All Subjects	60	35	25	6.05	3.30	13/10
Non-Nasal Group (n = 38)	SMC	7	0	7	6.00	2.29	14/5
	CP	14	6	8	6.00	2.36	10/11
	UCL & P	12	11	1	6.00	2.83	11/5
	BCL & P	5	5	0	5.80	3.00	12/10
	Non-Nasal	38	22	16	5.97	2.57	12/0
Nasal Group (n = 22)	SMC	7	0	7	6.14	4.29	11/7
	CP	6	4	2	6.00	4.83	25/9
	UCL & P	6	6	0	6.17	4.50	18/5
	BCL & P	3	3	0	6.67	4.67	9/5
	Nasal	22	13	9	6.18	4.54	17/0

non-nasal speech (non-nasal group) and those who still had some degree of nasal speech (nasal group) after the pharyngeal flap operation are presented in Table 2. In the submucous and bilateral cleft lip and palate groups, cleft type did not appear to be a factor which differentiated success from failure in the post-operative quality of speech. A higher per cent of success was obtained in the cleft palate only and unilateral cleft lip and palate group, but this finding seemed to be related more to the age differences. Thus, it could not be concluded that cleft type was a strong determining factor relative to potential success or failure.

The surgical status of the patient did not definitively indicate what effect previous palatal surgery or the absence of it would have on the potential success of the pharyngeal flap procedure (Table 3). Likewise, pre-operative nasality rating was not found to be a differentiating factor relative to surgical success or failure. The correlation coefficient found between pre- and post-operative nasality rating was .008; this was surprisingly low, and indicated that pre-operative nasality ratings had no real influence on the potential success of surgery.

TABLE 3. The relative number and per cent of operated and unoperated subjects that had non-nasal or nasal speech following pharyngeal flap surgery.

Surgical Status Before Flap	*No. of Subjects*	*Non-Nasal Group*		*Nasal Group*	
		n	%	*n*	%
Operated	35	22	63%	13	37%
Unoperated	25	16	64%	9	36%

Age at the time of operation was found to be significantly related to the potential success of flap surgery. The mean age of the total sample was 13 years, 10 months. The non-nasal group had a mean age of 12 years as compared to 17 years for the nasal group.

Comparative Pre and Post-Operative Anatomy of the Non-Nasal and Nasal Groups (*based on cephalometric measurements*). The anatomical differences between the subjects who obtained non-nasal speech and those who still had some degree of nasal speech after the flap operation are reported in Table 4, and diagrammatically illustrated in Figure 5. Differences between the two groups were found in several areas; however, only the measurements that are pertinent to the present discussion will be presented.

Angle NSP indicated that the chin was relatively farther away from the anterior cranial base in the non-nasal group, which might also indicate a greater vertical dimension to the oral cavity in this group. Angle SNP showed that the mandible was more retruded in the non-nasal group, which could be a reflection of more mandibular growth in the older subjects of the nasal group. Thus, while at rest or in a relaxed position, the mandible of the non-nasal group was postured in a more open and retruded position, before and after flap surgery, when compared to the nasal group (Figure 5). Likewise, the tongue and hyoid bone were postured in a more retruded position in the non-nasal group.

The length of the soft palate was essentially the same for both groups; however, the soft palate at rest was found to be positioned significantly higher and in a closer approximation to the posterior pharyngeal wall in the non-nasal group (Figure 5). Additionally, although not significant, a shorter depth of the nasopharynx was observed in the non-nasal group. The comparative difference in the nasopharyngeal depth was relatively small (2.5 millimeters).

Subsequent to pharyngeal flap surgery, it was found that the flap base attachment was located at a significantly higher level along the pharyngeal wall in the non-nasal group than in the nasal group (Figure 5). By utilizing planimetric nasopharyngeal area measurements it was found that the subjects in the non-nasal group had significantly smaller nasopharynges before and after surgery. The nasopharyngeal area, as well as being smaller, also showed a slightly larger percentage of reduction in size as a

TABLE 4. Means, standard deviations and significance for measures defining anatomical relationships during rest for pre and post-operative conditions. Data is subdivided on the basis of post-operative nasality ratings. (non-nasal group, n = 38; nasal group, n = 22)

Rest Measurements		*Non-Nasal*		*Nasal*		*Sig.*
		Mean	*SD*	*Mean*	*SD*	
Position of Mandible						
Angle NSP	Pre	68.9°	3.3	66.9°	3.9	—
	Post	69.6°	3.4	66.1°	4.3	.01
Angle SNP	Pre	75.0°	3.2	76.9°	4.1	—
	Post	74.7°	3.5	77.5°	4.6	.05
Position of Tongue						
Vertical						
(HT-PP)	Pre	12.0 mm	5.3	12.3 mm	4.0	—
	Post	12.3 mm	4.1	12.8 mm	3.7	—
(PT-PP)	Pre	38.3 mm	7.5	39.4 mm	10.3	—
	Post	38.2 mm	8.5	38.9 mm	7.1	—
Horizontal						
(HT-PTM)	Pre	6.9 mm	6.3	9.0 mm	6.1	—
	Post	7.5 mm	6.6	7.8 mm	8.5	—
(PT-PTM)	Pre	24.2 mm	6.6	21.3 mm	6.8	—
	Post	23.8 mm	6.0	20.7 mm	5.5	.05
(PT-PW)	Pre	9.3 mm	3.9	10.1 mm	3.2	—
	Post	6.9 mm	2.8	7.0 mm	2.4	—
Position of Hyoid						
Vertical (H-PP)	Pre	55.5 mm	11.6	59.8 mm	10.8	—
	Post	59.8 mm	8.5	63.0 mm	10.2	—
Horizontal (H-PTM)	Pre	−7.7 mm	7.5	−4.7 mm	7.1	—
	Post	−8.0 mm	7.0	−2.3 mm	6.5	.01
Velum and Pharyngeal Flap						
Length						
(PNS-U)	Pre	26.9 mm	4.2	25.9 mm	4.9	—
(PI-U)	Pre	23.5 mm	4.2	23.7 mm	4.9	—
Linear Position (V-PH)	Pre	20.1 mm	5.4	22.4 mm	5.3	—
Angular Velar Position						
(ANS-PI-U)	Pre	130.3°	11.1	126.7°	8.6	—
(ANS-PNS-U)	Pre	138.3°	9.7	131.7°	8.5	.05
Angular Flap Position						
(ANS-PI-MF)	Post	150.8°	9.4	144.6°	10.8	.05
(ANS-PNS-MF)	Post	154.6°	9.1	147.2°	10.7	.05
(NF-PNS-MF)	Post	7.9°	8.2	5.7°	8.3	—
Thickness of Posterior Pharyngeal Wall						
Tissue Overlay Atlas (A-PW)	Pre	6.2 mm	3.3	5.1 mm	2.2	—
	Post	7.8 mm	3.0	6.8 mm	2.7	—
Nasopharyngeal Depth, Height, and Area						
Depth (PI-PH)	Pre	21.7 mm	5.0	24.2 mm	5.5	—
	Post	20.9 mm	4.3	22.8 mm	4.8	—
Height (PI-Cranial Base)	Pre	23.3 mm	3.4	23.7 mm	4.4	—
Nasopharyngeal Area	Pre	410.2 mm^2	158.2	506.8 mm^2	140.8	.05
	Post	383.3 mm^2	140.5	480.4 mm^2	149.5	.05
% Nasopharyngeal Area Reduction (Pre-Post)	Post	7.4%	26.2	4.0%	21.6	—
Length and Position of Pharyngeal Flap Base						
Attachment Length (SF-IF)	Post	20.8 mm	6.1	19.6 mm	4.3	—
Vertical Position (MF-PP)	Post	14.5 mm	5.6	18.4 mm	6.8	.05
Horizontal Position (MF-PTM)	Post	24.8 mm	3.6	24.9 mm	3.9	—

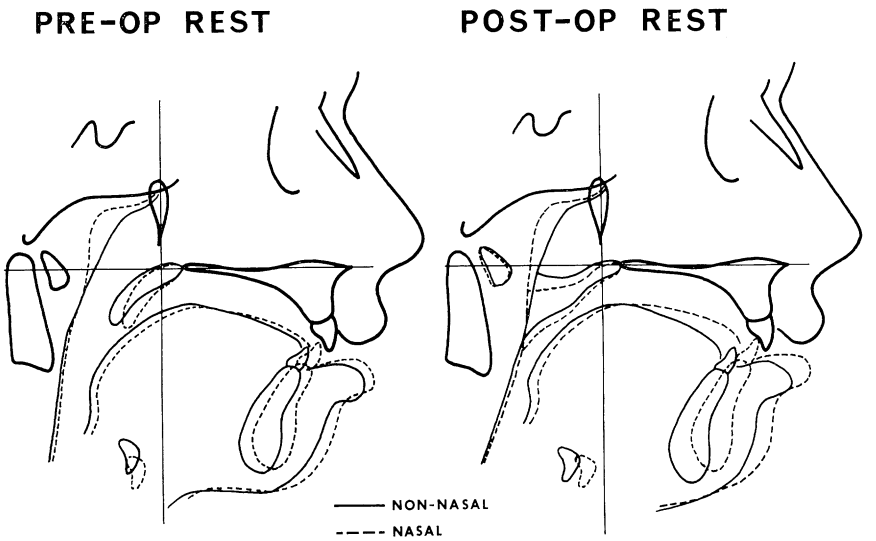

FIGURE 5. Diagrammatic pre-operative and post-operative superimpositions of the non-nasal and nasal groups at rest position. The tracings were done on scaled transparent graph paper, and represent the means of the measurements in this study. Anatomical differences between the non-nasal and nasal groups are graphically illustrated.

result of the pharyngeal flap procedure; thus indicating a higher surgical positioning of the pharyngeal flap.

A subjective evaluation regarding the shape of the nasopharynx revealed that approximately one-half of the subjects in the nasal group as compared to one-fourth in the non-nasal group had a "box-shaped" configuration to the nasopharynx. That is, the supero-posterior contour of the nasopharynx was extended more in a backward direction along the cranial base; thus giving a box-shaped appearance, and consequently a larger area (Figure 5). In addition, subjective evaluation revealed a greater abundance of adenoid tissue present in the non-nasal group.

In summary, analysis of the pre-operative anatomy revealed two statistically significant differences between the non-nasal and nasal speakers. The non-nasal group had higher angular positions of the soft palate and smaller nasopharyngeal areas. Other tendencies which were indicated in the pre-operative measures became statistically significant after surgery. These included a more open and retruded position of the mandible, and a more retruded tongue and hyoid position in the non-nasal group. The non-nasal speakers also displayed higher pharyngeal flap base attachments along the posterior pharyngeal wall, and smaller nasopharyngeal areas after flap surgery. The shorter nasopharyngeal depth, the greater abundance of adenoid tissue, the fewer subjects with a box-type nasopharynx, and the higher positioned soft palates and pharyngeal flaps seemed to

contribute to the smaller nasopharyngeal areas displayed by the non-nasal speakers.

COMPARATIVE PRE- AND POST-OPERATIVE FUNCTIONAL RELATIONSHIPS OF THE NON-NASAL AND NASAL GROUPS. *Phonation of vowel /u/:* The most prominent functional differences found between the non-nasal and nasal groups during sustained phonation of vowel /u/ were related to the nasopharyngeal region (Table 5). Functional differences between the two groups are diagrammatically illustrated in Figure 6. Pre-operative measures between the velum and posterior pharyngeal wall (V-PH & V-PW) revealed a significantly smaller palatopharyngeal opening in those cases which post-operatively became part of the non-nasal group. The site of maximum palatopharyngeal constriction (VC-PP, VC-PNS-PH) was also located at a significantly higher level in the nasopharynx in the non-nasal group.

Post-operatively, the middle third of the nasal surface of the flap (NF-PNS-MF) was elevated about the same extent in both groups. However, the pharyngeal flap base was positioned significantly higher in the non-nasal group (ANS-PNS-MF, MF-PP) during phonation of /u/; thus, encroachment of elevated velar-flap tissue into the nasopharynx was greater in the non-nasal group. Because of the higher velar and pharyngeal flap elevation, the percentage of nasopharyngeal area reduction was found to be significantly greater in the non-nasal group as compared to the nasal group (Table 5 and Figure 6).

In summary, the major differentiating factors between the non-nasal and nasal groups during phonation of /u/ were related to the nasopharyngeal region. Pre-operatively, the non-nasal group had the following significant features: a smaller palatopharyngeal opening; greater elevation of the soft palate; a higher site of palatopharyngeal constriction; a greater percentage reduction of the nasopharyngeal area; and a smaller nasopharyngeal area. After surgery, the significant features of the non-nasal group were: higher positioning of the flap base attachment; greater percentage area reduction of the nasopharyngeal area; and a smaller nasopharyngeal area. It should also be noted that the nasal group had a significantly lower tongue position both pre- and post-operatively during phonation of vowel /u/. Pre-operatively, the lower tongue posturing could possibly indicate faulty compensatory tongue movement in an attempt to reduce nasal air escape as the result of palatopharyngeal incompetence. Since the nasal group had a significantly lower positioned pharyngeal flap base during function, the lower posturing of the tongue post-operatively may be necessary to maintain an adequate oral opening during function.

Production of /s/: Fewer measurements differentiated the non-nasal and nasal groups during sustained production of /s/ than during the phonation of vowel /u/. The measurements which differentiated non-nasal from nasal speakers during production of /s/ were limited to the naso-

TABLE 5. Means, standard deviations and significance for measures defining functional relationships during phonation of /u/ for pre and post-operative conditions. Data is subdivided on the basis of post-operative nasality ratings. (non-nasal group, n = 38; nasal group, n = 22)

Measurement /u/		*Non-Nasal*		*Nasal*		*Sig.*
		Mean	*SD*	*Mean*	*SD*	
Vertical Position of Tongue						
Vertical						
(HT-PP)	Pre	10.5 mm	4.6	12.4 mm	5.2	—
	Post	11.0 mm	4.8	14.1 mm	5.8	.05
(PT-PP)	Pre	27.1 mm	6.2	31.7 mm	7.3	.05
	Post	31.0 mm	6.8	34.0 mm	8.4	—
Velum and Pharyngeal Flap						
Linear Position (V-PH)	Pre	9.1 mm	5.6	13.4 mm	7.5	.05
Velo-Pharyngeal Opening (V-PW)	Pre	4.9 mm	3.2	8.1 mm	4.3	.01
Site of Velo-Phar. Constrict. (VC-PP)	Pre	−.7 mm	5.2	−4.6 mm	6.7	.05
Angular Position of Velo-Phar. Constriction (VC-PNS-PH)	Pre	−1.1°	12.3	−11.4°	15.5	.05
Angular Velar Position						
(ANS-PI-U)	Pre	141.0°	10.2	138.2°	9.8	—
(ANS-PNS-U)	Pre	147.9°	8.0	142.3°	9.4	.05
Angular Flap Position						
(ANS-PI-MF)	Post	156.6°	10.2	146.7°	11.1	.01
(ANS-PNS-MF)	Post	159.6°	9.6	149.0°	10.3	.01
(NF-PNS-MF)	Post	24.4°	11.0	23.9°	14.0	—
Thickness of Posterior Pharyngeal Wall						
Tissue Overlay Atlas (A-PW)	Pre	6.2 mm	3.3	4.6 mm	1.8	.05
	Post	7.7 mm	2.9	6.9 mm	2.7	—
Nasopharyngeal Depth, Area, and Area Reduction						
Depth (PI-PH)	Pre	21.1 mm	5.8	24.1 mm	5.3	—
	Post	20.9 mm	4.6	22.7 mm	4.7	—
Nasopharyngeal Area	Pre	254.7 mm	127.8	382.2 mm	161.6	.01
	Post	269.4 mm	107.1	383.1 mm	143.2	.01
% Nasopharyngeal Area Reduction (Rest—/u/)	Pre	37.3%	22.1	25.3%	18.1	.01
	Post	33.2%	31.1	19.9%	15.7	.05
Length and Position of Pharyngeal Flap Base						
Attachment Length (SF-IF)	Post	23.5 mm	6.0	21.7 mm	6.4	—
Horizontal Position (MF-PTM)	Post	25.0 mm	3.4	25.1 mm	4.2	—
Vertical Position (MF-PP)	Post	11.3 mm	6.2	16.7 mm	6.6	.01

NOTE: Comparative measures of mandibular position, horizontal tongue posture, and hyoid position did not significantly differentiate the two groups, and are not presented.

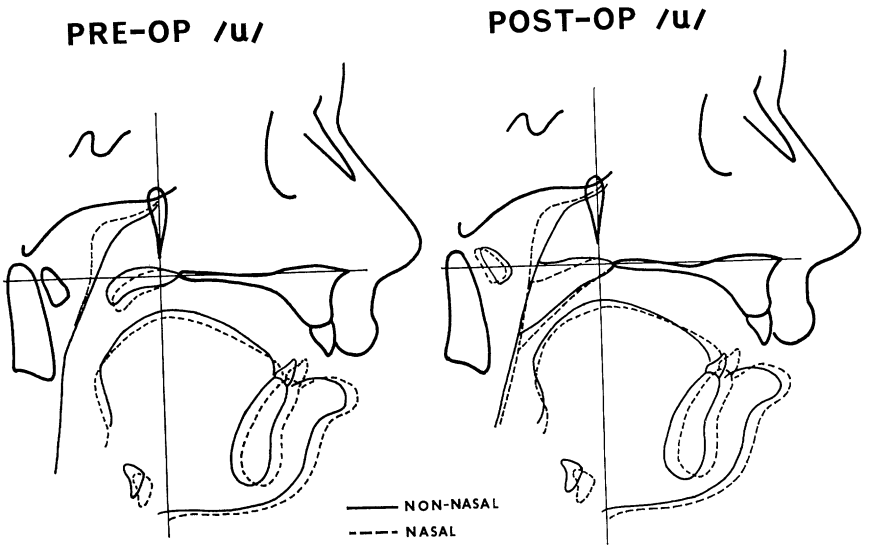

FIGURE 6. Diagrammatic representations of pre-operative and post-operative superimpositions of the non-nasal and nasal groups during phonation of /u/. The tracings were done on scaled transparent graph paper, and represent the means of the measurements in this study. Functional differences between the non-nasal and nasal groups are graphically illustrated.

pharyngeal region. These comparative measures are reported in Table 6 and diagrammatically illustrated in Figure 7.

Pre-operatively, the following features significantly differentiated the non-nasal and nasal groups during production of /s/: the non-nasal group had greater velar elevation with a higher site of palatopharyngeal constriction; a smaller nasopharyngeal depth; and a smaller nasopharyngeal area. After surgery, the non-nasal group had a higher flap base positioning; a greater percentage reduction of the nasopharyngeal area; and a smaller nasopharyngeal area.

Soft Palate (Velar) and Pharyngeal Flap Mobility. By planimetrically measuring the areas of the nasopharynx at rest and during function, the actual area reduction, and percentage of area reduction which occurred as a result of upward velar and pharyngeal flap mobility, as well as any possible anterior movement of the posterior pharyngeal wall could be effectively evaluated. Thus, planimetric measurements served to either confirm or reject the findings of other clinical type measurements that were used to evaluate the pre and post-operative dynamics of the nasopharyngeal region.

Pre-Operative Velar Mobility: Velar elevation was evaluated by paired observations of the soft palate at rest and during function. The results are reported in Table 7. To quantitate the increment of elevation of the middle third of the soft palate Angle ANS-PNS-U at rest was compared with

TABLE 6. Means, standard deviations and significance for measures defining functional relationships during production of /s/ for pre and post-operative conditions. Data is subdivided on the basis of post-operative nasality ratings. (non-nasal group, n = 38; nasal group, n = 22)

Measurement /s/		*Non-Nasal*		*Nasal*		*Sig.*
		Mean	*SD*	*Mean*	*SD*	
Velum and Pharyngeal Flap						
Linear Position (V-PH)	Pre	10.9 mm	7.1	15.2 mm	9.9	—
Velo-Pharyngeal Opening (V-PW)	Pre	6.3 mm	3.7	8.4 mm	4.5	—
Site of Velo-Phar. Constrict. (VC-PP)	Pre	−.6 mm	5.5	−7.0 mm	8.6	.01
Angular Position of Velo-Phar. Constrict. (VC-PNS-PH)	Pre	−1.4°	12.7	−15.2°	17.2	.01
Angular Velar Position						
(ANS-PI-U)	Pre	135.3°	13.9	134.6°	11.3	—
(ANS-PNS-U)	Pre	143.0°	10.6	139.1°	10.9	—
Angular Flap Position						
(ANS-PI-MF)	Post	158.4°	10.6	150.7°	11.1	.05
(ANS-PNS-MF)	Post	161.8°	10.2	152.8°	10.3	.01
(NF-PNS-MF)	Post	25.0°	9.4	26.4°	13.0	—
Thickness of Posterior Pharyngeal Wall						
Tissue Overlay Atlas (A-PW)	Pre	6.1 mm	3.1	5.4 mm	2.1	—
	Post	7.4 mm	2.9	7.2 mm	2.9	—
Nasopharyngeal Depth, Area, and Area Reduction						
Depth (PI-PH)	Pre	21.5 mm	5.0	25.0 mm	4.9	.05
	Post	19.8 mm	4.6	22.8 mm	6.5	—
Nasopharyngeal Area	Pre	293.7 mm^2	125.4	418.9 mm^2	143.3	.01
	Post	247.7 mm^2	117.4	355.0 mm^2	120.6	.01
% Nasopharyngeal Area Reduction (Rest—/s/)	Pre	29.6%	23.5	17.0%	20.3	—
	Post	34.7%	17.1	23.7%	16.2	.05
Length and Position of Pharyngeal Flap Base						
Attachment Length (SF-IF)	Post	24.6 mm	5.7	22.5 mm	6.9	—
Vertical Position (MF-PP)	Post	9.6 mm	6.2	−14.2 mm	7.2	—
Horizontal Position (MF-PTM)	Post	23.3 mm	4.3	24.9 mm	4.0	—

Angle ANS-PNS-VC during production of the /u/ and /s/ sounds (Figure 8).

Velar elevation was found to be substantially greater in the non-nasal group although the mean difference between the two groups was not sta-

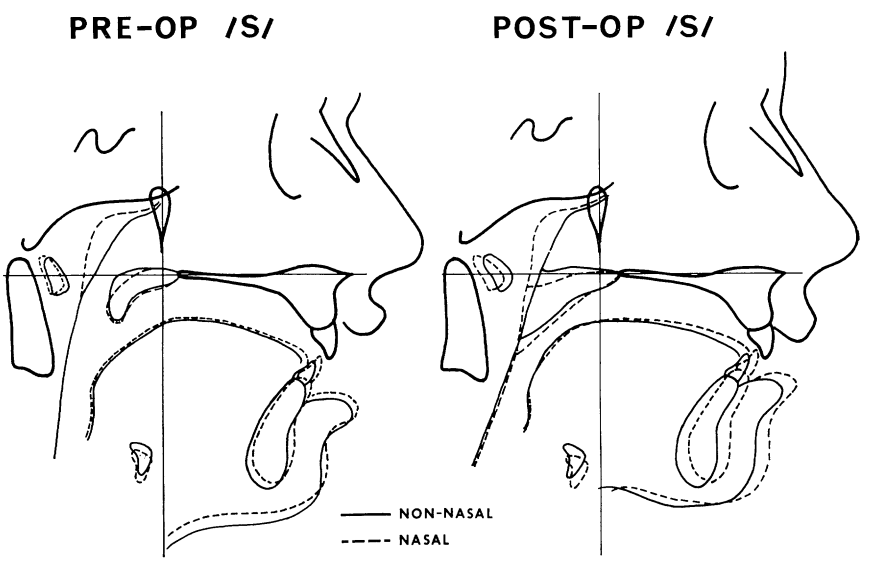

FIGURE 7. Diagrammatic representations of pre-operative and post-operative superimpositions of the non-nasal and nasal groups during production of /s/. The tracings were done on scaled transparent graph paper, and represent the means of the measurements in this study. Functional differences between the non-nasal and nasal groups are graphically illustrated.

tistically significant. However, the soft palate at rest was positioned significantly higher and farther back in the non-nasal group (Table 4, Figures 5 and 9). As indicated by the percentage of nasopharyngeal area reduction, the effect of the higher velar rest position in the non-nasal group plus the greater increment of velar elevation resulted in a substantially higher elevated position of the middle third of the soft palate during production of both the /u/ and /s/ sounds (Table 7 and Figure 9). Thus, the non-nasal group had significantly smaller velopharyngeal openings (V-PW) with significantly higher sites of maximum velopharyngeal constriction (VC-PP).

Post-Operative Flap Mobility: Post-operatively, the non-nasal group demonstrated significantly greater flap base elevation than the nasal group (Table 7). To evaluate mid-flap elevation, measurement NF-PNS-MF was used as shown in Figure 10. Substantial elevation of the middle third of the flap occurred with both groups exhibiting approximately the same extent of mid-flap elevation. But since the flap base was positioned significantly higher at rest in the non-nasal group (Table 4, Figures 5 and 11), the elevated mid-flap tissue encroached into the nasopharyngeal area significantly more in the non-nasal group. This was verified by the area and percentage area reduction measurements of the nasopharynx (Table 7, Figures 5 and 11).

In summary, planimetric measurements of the nasopharyngeal area

TABLE 7. Comparative analysis of soft palate and flap mobility between the non-nasal and nasal groups. Mobility is defined by paired observations of measurements at rest and during function of /u/ and /s/ sounds. Sample sizes are as follows: Pre-operative (non-nasal, rest—/u/, n = 38; rest—/s/, n = 35); (nasal, rest—/u/, n = 22; rest—/s/, n = 19). Post-operative (non-nasal, rest—/u/, n = 38; rest—/s/, n = 36; (nasal, rest—/u/, n = 22; rest—/s/, n = 22).

Measurement		*Non-Nasal Mean Diff.*	*Nasal Mean Diff.*	*t*
Pre-Operative Velar				
ANS-PNS-U (rest)—	Rest—/u/	42.82°	36.23°	1.56
VC-PNS-PH (converted)†	Rest—/s/	40.19°	31.74°	1.69
Site of Velo-Phar. Constrict. (VC-PP)	Rest—/u/	−0.92 mm	−4.68 mm	2.17*
	Rest—/s/	−1.39 mm	−7.05 mm	4.03**
Velo-Pharyngeal Constrict. (V-PW)	Rest—/u/	4.98 mm	8.11 mm	2.95**
	Rest—/s/	6.37 mm	8.42 mm	1.35
Nasopharyngeal Area Reduction	Rest—/u/	160.00 mm^2	124.55 mm^2	1.58
	Rest—/s/	140.00 mm^2	92.63 mm^2	1.65
% Nasopharyngeal Area Reduction	Rest—/u/	37.66%	26.92%	2.24*
	Rest—/s/	29.63%	17.05%	2.68*
Post-Operative Flap				
Mid-Third Flap Mobility (NF-PNS-MF)	Rest—/u/	17.62°	19.55°	0.48
	Rest—/s/	18.00°	21.75°	0.96
Vertical Flap Base Position (MF-PP)	Rest—/u/	3.45 mm	1.64 mm	2.53*
	Rest—/s/	8.75 mm	4.11 mm	4.72**
Nasopharyngeal Area Reduction	Rest—/u/	109.47 mm^2	97.27 mm^2	0.53
	Rest—/s/	130.00 mm^2	120.00 mm^2	0.19
% Nasopharyngeal Area Reduction	Rest—/u/	33.17%	19.86%	2.22*
	Rest—/s/	34.69%	23.67%	2.53

* Significant at the .05 level

** Significant at the .01 level

† Functional measurement Angle VC-PNS-PH was mathematically converted to Angle ANS-PNS-VC, thereby making it possible to compare the rest and functional positions of the soft palate.

NOTE[1]: The negative (−) values for VC-PP indicate that the site of velopharyngeal constriction was below the palatal plane.

NOTE[2]: All paired observations of soft palate and pharyngeal flap mobility, for both non-nasal and nasal subjects, were significant at the .01 level.

confirmed the findings of the other clinical type measurements; that is, that the non-nasal group had significantly greater pre-operative velar elevation, greater pharyngeal flap base elevation, and consequently greater middle-third flap elevation.

Correlation and Regression Analyses. One of the objectives of the present study has been to determine anatomic and physiologic criteria which could indicate potential success and/or failure of pharyngeal flap surgery. Therefore, efforts were made to study the specific nature and strength of the relationships between selected pre-operative cephalometric measures which seemed to differentiate success and failure of the pharyn-

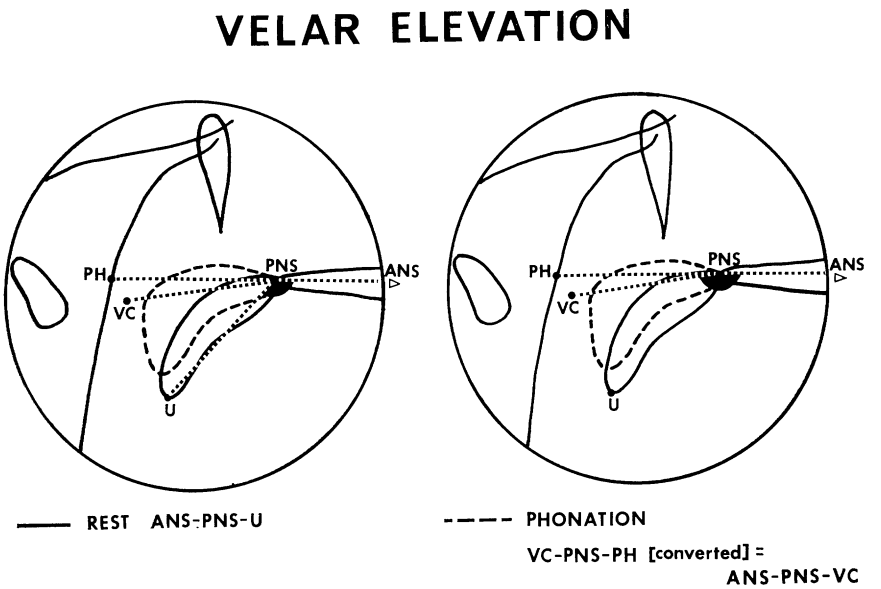

FIGURE 8. This figure illustrates the method in which velar elevation was evaluated. The difference between Angle ANS-PNS-U at rest and Angle ANS-PNS-VC during phonation represents velar elevation.

geal flap procedure. Correlation and regression analyses were used for this purpose as well as to obtain a set of measures which in combination would begin to explain a major portion of the variability in post-operative nasality rating.

By utilizing regression analysis, a strong beginning to understand the specific nature of the effects of each measure on post-operative surgical effectiveness has been made. Despite the fact that the nasality rating is subject to step function limitations (Figure 12), it is sufficiently possible to trace the effect of each independent variable acting both individually and in concert with other measures, examining such things as: (a) the apparent strength of the effect; (b) whether the effect is positive or negative; and (c) whether the effect is reasonably linear or requires a more complex curvilinear function to describe it. To date, all curvilinear refinements have been limited to the addition of the square term.

Having subjected the data to classical statistical analysis, as described in the previous sections, some of the comparisons (pre-operative measures) demonstrated strong differences between the non-nasal and nasal groups. These differences indicated a strong relationship to surgical success and/or failure as defined by post-operative nasality ratings. This group of pre-operative measures was further reduced by eliminating the highly correlated independent variables which were mainly reflective of each other. From this group of pre-operative measures, judgemental selection was made among statistically equal alternatives for use in this initial

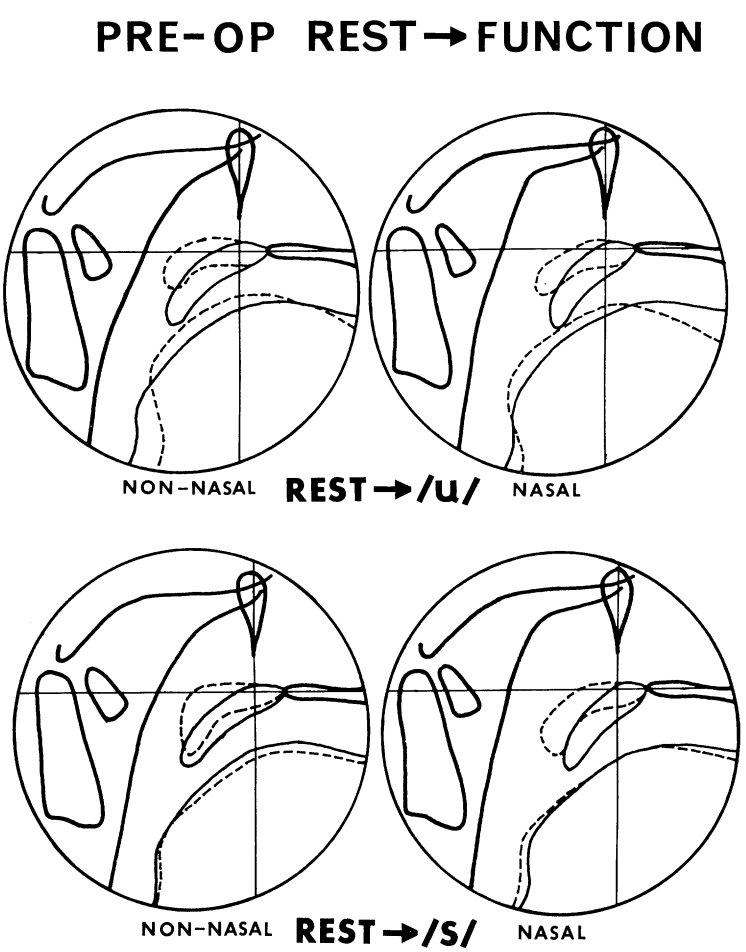

FIGURE 9. Diagrammatic representations of pre-operative superimpositions of rest and the functional positions of the sustained /u/ and /s/ sounds. The tracings were done on scaled transparent graph paper, and represent the means of the measurements of the nasopharyngeal region. The tracings graphically illustrate the mean changes occurring from rest to phonation in both the non-nasal and nasal groups.

study. Thus, a set of pre-operative measures (independent variables) were selected and found to be concertedly related to the potential adequacy of pharyngeal flap surgery. The pre-operative features included in the best regression model obtained to date are as follows: mandibular and tongue position; soft palate mobility; site of maximum velopharyngeal constriction; extent of velopharyngeal closure; nasopharyngeal depth; area size of the nasopharynx; reduction of the nasopharyngeal area during function; and age at the time of surgery (Table 8). This model yielded a multiple correlation coefficient of .811; thus explaining 66 per cent of the end result of pharyngeal flap surgery as described by post-operative nasality rating.

The correlation and regression analyses were run on 54 subjects in

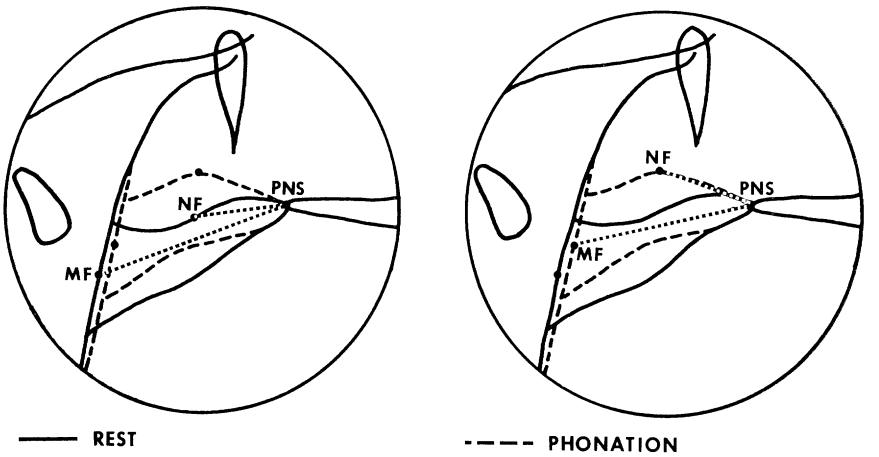

FIGURE 10. This figure illustrates Angle NF-PNS-MF measured at rest and during phonation. The diffrence between the values at rest and phonation represents mid-flap elevation. Since movement of the middle third of the flap was measured relative to the flap itself (Line PNS-MF), upward movement of the flap base attachment was not a consideration in evaluating mid-flap elevation.

which complete pre- and post-operative data were available; 19 subjects had post-operative nasality ratings of 4 and above, and 35 subjects had post-operative nasality ratings of 3 or below. Of the 19 patients who remained inadequately corrected following surgery, 15 would have been predicted by this model; the four that would not have been predicted had a post-operative nasality rating of 4, one rating removed from the normal nasality rating of 3. Of the 35 patients in which adequate correction was obtained, only two would have had a prediction of inadequate correction, and these were both predictions of 4.

In summary, the results obtained to date have indicated that a combination of factors are working in concert in a logical and predictable manner; thus, a high degree of predictability of post-operative nasality rating can be demonstrated. The above model, based on pre-operative variables, would have predicted success or failure of the pharyngeal flap procedure in 48 of the 54 cases in this study. These findings have indicated substantial progress toward clinical prognosis and treatment of individuals with palatopharyngeal incompetence. However, before clinical use of the findings can be recommended, further study is required.

Discussion

The comparative cephalometric data in this study has indicated that pre-operative anatomic and physiologic relationships may have a definite influence on the success or failure of the pharyngeal flap operation. Fac-

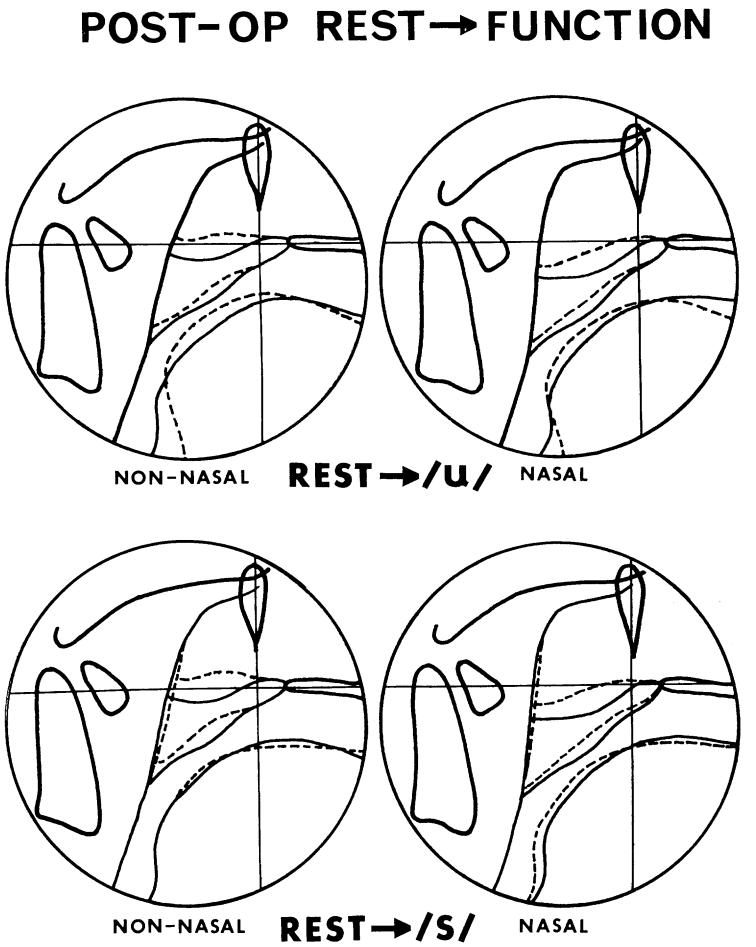

FIGURE 11. Diagrammatic representations of post-operative superimpositions of rest and the functional positions of the sustained /u/ and /s/ sounds. The tracings were done on scaled transparent graph paper, and represents the means of the measurements of the nasopharyngeal region. The tracings graphically illustrate the mean changes occurring from rest to phonation in both the non-nasal and nasal groups.

tors other than anatomical and functional characteristics which might influence the eventual result of pharyngeal flap surgery were also a consideration in this study. These factors included: cleft type; surgical status (operated or unoperated); pre-operative nasality ratings; and age at the time of surgery.

In this study, cleft type could not definitively be shown to be a factor related to potential success of flap surgery. Based on speech ratings and oral breath pressure measures, Moll and associates (7) also found no marked intergroup differences, thus, indicating that the etiology of the palatopharyngeal problem does not appear to be related to success of the

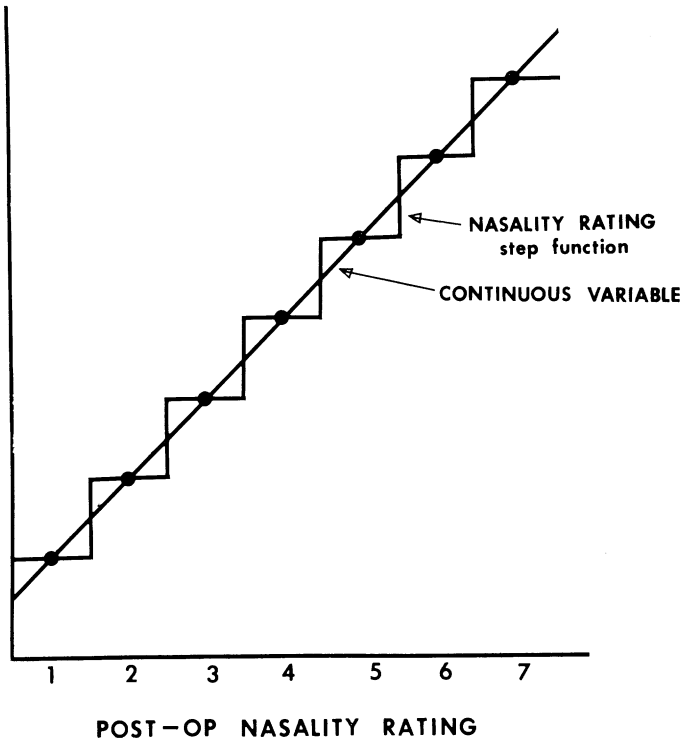

FIGURE 12. Schematic comparison of step function (rating scale) versus a continuous variable. Note that a 1.00 correlation coefficient of nasality rating is impossible to obtain, because the correlation coefficient measures only the degree of a strictly linear relationship.

pharyngeal flap procedure. Likewise, the effect of previous palatal surgery or the absence of it could not be shown to be related to the potential success of the pharyngeal flap procedure (Table 3). The correlation coefficient between pre- and post-operative nasality rating was found to be .008, which indicated that pre-operative nasality rating had no real influence on the potential success of flap surgery. Age at the time of operation, however, was found to be significantly related to the potential success of flap surgery. Whether considered in terms of speech or in terms of palatopharyngeal adequacy, this finding is in agreement with other investigators (*7, 13*). The subjects who obtained non-nasal speech (non-nasal group) as a result of flap surgery had a mean age of 12 years as compared to a mean age of 17 years for those who still had some degree of nasal speech (nasal group) after the pharyngeal flap procedure. It has also been suggested that less improvement in older patients may be related to their inability to overcome faulty speech patterns (*8*).

PRE-OPERATIVE ANATOMY AND PHYSIOLOGY. The pre-operative data revealed that subjects in the non-nasal group had higher and more retropo-

TABLE 8. Basic results of the sample regression run involving the pre-operative measures of interest where both first and second order terms have been used. The data included that of the 54 subjects in which all pre and post-operative data was available.

Response Variable: Post-Operative Nasality Rating	
Independent Variables:	*Cephalometric Posture (Rest, /u/, /s/)*
Position of Mandible	
1. Angle NSP (Vertical)	Rest
2. Angle SNP (Horizontal)	Rest
Posterior Aspect of Tongue	
7. PT-PTM (Horizontal)	Rest
8. PT-PP (Vertical)	/u/
Position of Soft Palate	
14. ANS-PNS-U (Angular)	Rest
16. VC-PP (Site of Velo-phar. Constriction)	/u/
16. VC-PP (Site of Velo-phar. Constriction)	/s/
17. V-PH (Position to Pharyngeal Wall)	/u/
18. V-PW (Velo-phar. Opening)	/u/
Nasopharyngeal Depth, Area, and Area Reduction	
20. PI-PH (Depth)	Rest
22. Nasopharyngeal Area	Rest
	/u/
	/s/
23. Nasopharyngeal Area Reduction	/u/
Multiple Correlation Coefficient: .811	
Percent Variability Isolated: 66%	
Standard Error of Estimate: 1.126	

Predictability	*No.*	*%*	*Cum. %*
Within ½ Rating	32	59	59
Between ½ and 1 Rating	13	24	83
Over 1 Rating	9	17	100
Total	54	100	

sitioned soft palates, both at rest and during function. As a result of greater velar mobility, the non-nasal group had smaller palatopharyngeal openings with higher sites of maximum palatopharyngeal constriction. The extent of palatopharyngeal closure also appeared to be related to an anatomically shorter nasopharyngeal depth in the non-nasal group. When considering these factors together, the non-nasal group had, on the average, shorter nasopharyngeal depths, and soft palates with greater upward and backward movement, which resulted in a smaller palatopharyngeal

opening located at a higher site in the nasopharynx. Thus, the non-nasal group had a pre-operative palatopharyngeal anatomy and functional mechanism that more closely approached the normal than did the subjects in the nasal group.

Planimetric area measurements revealed that the size of the nasopharynx was significantly smaller at rest and during function in the non-nasal group. Several factors seemed to explain this finding. The non-nasal group had a greater abundance of adenoid tissue, thereby reducing the size of the nasopharyngeal air space. This finding appeared to be related to the younger age of the subjects in the non-nasal group, in that the peak of greatest adenoid growth and bulk is evident at about 10 to 14 years of age (*16*). The greater depth and area of the nasopharynx as seen in the nasal group may partially be the result of adenoid tissue atrophy as well as physical increase in size incident to growth with increment in age (*15*). The observation that more subjects in the nasal group had "box-shaped" configurations to the nasopharynx would also help to explain this finding. It has also been observed (*12*) that in some cases the posterior cranial base may be more horizontal, thereby serving to increase the anteroposterior dimension of the nasopharynx. Hynes (*5*), who stated that an "overlarge" nasopharynx is often seen in cleft palate patients, concurs with Ricketts (*12*) in that a nasal quality in speech can be related to an excessively large nasopharynx. Whether partially due to age, growth, congenital configuration, or adenoid mass, the present findings indicate that the relative size of the nasopharyngeal air space is significantly identified with success and/or failure of the pharyngeal flap procedure. It was also found that the average nasopharyngeal air space, in addition to being anatomically smaller in the non-nasal group, was concomitantly significantly reduced in size by a greater elevation of the soft palate during function. This finding confirmed the other measures which had indicated greater velar elevation in the non-nasal group.

The influence of tongue posture on velar mobility and palatopharyngeal closure as it relates to the pharyngeal flap procedure seems inconclusive. However, there did appear to be a relationship between vertical positioning of the tongue, velar mobility, and the extent of palatopharyngeal closure. During phonation of vowel /u/, a generally higher posturing of the tongue as well as a significantly greater degree of palatopharyngeal closure was observed in the non-nasal group; whereas during production of /s/, in which vertical tongue posture was essentially the same for both groups, the extent of palatopharyngeal closure was not significantly different. Because of the direct anatomical connection between the soft palate and the tongue, it is reasonable to assume that lack of tongue elevation may restrict velar mobility and palatopharyngeal closure. A lesser amount of mandibular growth in the younger non-nasal group might also partially explain the difference in tongue positioning between the two groups (*15*). Regardless of explanation, it would seem that both the /u/

and /s/ cephalometric radiographs should be used in evaluating tongue and palatal function relative to pre-operative velar mobility and palatopharyngeal closure.

Post-Operative Anatomy and Physiology. The post-operative data revealed that the non-nasal group had pharyngeal flap base attachments: (1) located at a significantly higher level along the posterior pharyngeal wall; and (2) with significantly greater elevational mobility during sound production. Several of the aforementioned pre-operative anatomical and functional conditions seemed to be related to a higher surgical positioning of the pharyngeal flap attachment, and to greatly enhance pharyngeal flap mobility. These included: a shorter nasopharyngeal depth; a smaller nasopharynx; a higher positioned soft palate at rest; and functionally greater velar mobility, thus enabling the height of maximum palatopharyngeal constriction to be located at a higher level within the nasopharynx.

The findings in this study have indicated that flap base elevation may be a very important factor for adequate palatopharyngeal valving, and that flap base elevation seems to occur more favorably when located nearer the site of normal palatopharyngeal closure. Owsley and others (*11*) observed clinically and from cinefluorographic films that palatopharyngeal closure takes place at the distal end of the soft palate, which is the site of the flap attachment. They also observed, as did Skoog (*13*), that reduced ability to elevate the palatal-flap tissue seemed in most instances to be the result of its posterior attachment to the pharyngeal flap. Owsley and others (*11*) also observed that the high attached pharyngeal flap makes use of levator palatine muscle function to achieve elevation and closure at the normal site of palatopharyngeal contact. Morris and Spriestersbach (*9*) described a mechanism whereby palatopharyngeal competence was accomplished in a manner similar to that observed in normal speakers; that is, that closure is accounted for primarily by the action of the palatal musculature. It has also been pointed out that the flap should be made loose enough to allow the palatal-flap tissue to contact the posterior pharyngeal wall on elevation (*2, 13*), and thus enhance the mechanism for the production of adequate palatopharyngeal closure. When the flap base attachment is located high, near the level of the palatal plane, it might more effectively make use of the contiguous musculature of the palatopharyngeal valving mechanism; that is, the combined compensatory medial movement of the lateral pharyngeal musculature and the elevational pull of the levator palatine musculature might be better utilized. In essence, the higher the pharyngeal flap base, the less of a "check-rein effect" the attachment will have on palatal-flap elevation and palatopharyngeal closure.

One of the major findings concerned with pharyngeal flap mobility and the potential success of the surgical procedure seemed to be related to the observation that the non-nasal speakers had smaller nasopharyngeal air spaces than the nasal speakers. Higher surgical and physiological positioning of the pharyngeal flap, greater flap elevation during function,

shorter nasopharyngeal depth, greater abundance of adenoid tissue and fewer subjects with "box-shaped" nasopharynges in the non-nasal group contributed to this finding. The size of the nasopharyngeal air space has itself been attributed as a factor related to nasal and/or non-nasal voice quality (*5, 12*). Warren (*21*) stated that an individual with high nasal resistance to airflow can obtain a given intraoral pressure for plosives with less air release from the lungs than an individual with the same degree of palatopharyngeal dysfunction but who has lower nasal resistance. Thus, the potential, anatomically and functionally, of attaining a sufficient reduction of the nasopharyngeal area would seem to be a necessary prerequisite for successful pharyngeal flap surgery and the attainment of non-nasal speech.

Summary

This study was undertaken in an effort to identify and differentiate anatomic and physiologic features associated with the success or failure of the pharyngeal flap procedure. Sixty patients in whom pharyngeal flap operations were performed, were separated into successful and unsuccessful groups by post-operative nasality ratings.

The comparative pre-operative cephalometric data revealed that the non-nasal speakers had: greater elevational velar mobility resulting in a smaller palatopharyngeal opening; a shorter nasopharyngeal depth; and a smaller nasopharyngeal area. These pre-operative features, as well as others, which included a younger age at the time of surgery, appear to be important requisites in attaining a high positioned pharyngeal flap base attachment that has good elevational mobility; thus enhancing the pharyngeal flap mechanism for the production of adequate palatopharyngeal closure during speech. The results of correlation and regression analyses of multiple pre-operative measures would have predicted post-operative results in 89 per cent of the cases studied.

Acknowledgements

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