Prosthetic and Speech Management of Patients with Velopharyngeal Incompetence

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Abstract

This article deals with a description of techniques used to assess patients with dysarthria of speech and accompanying velopharyngeal incompetence. A survey of perceptual and instrumental methods for assessing speech proficiency pre- and post-palatal lift placement are discussed. Emphasis is placed upon the continuing evaluation of respiratory, phonatory, resonatory and articulatory components of speech for the effective application of the lift appliance. A representative patient is presented to illustrate the evaluation process.

Introduction

One of the clinical problems encountered in human communication disorders is the determination of the most effective method of treatment for individuals suffering from velopharyngeal incompetency (VPI). These individuals present speech characteristics of hypernasality, excessive nasal emission of air, and decreased intelligibility. These communication difficulties accompanying VPI may occur as a result of congenital defects of the palate, traumatic injuries or cerebrovascular accidents, neuromuscular diseases, such as multiple sclerosis and amyotrophic lateral sclerosis, and tumors of the brain stem that have been surgically removed (Mazaheri and Mazaheri, 1976; LaVelle and Hardy, 1979).

One method of treatment for individuals with neurologically induced speech defects is the palatal lift prosthesis. Gibbons and Bloomer (1958) first described a prosthesis that was designed to elevate the soft palate and bring the velum close to the posterior pharyngeal wall for speech purposes. Since this first report, descriptions of the fabrication and application of the palatal lift have been published by Holley, Hamby and Taylor (1973) for young children with VPI aged 6 to 9 years, for cerebral palsied children (Hardy, Netsell, Schweiger and Morris, 1969), and for a variety of adult patients with anatomical or neurological problems resulting in VPI (Aten, McDonald, Simpson and Gutierrez, 1984; Gonzalez and Aronson, 1970; Kipfmueller and Lang, 1972; LaVelle and Hardy, 1979; Marshall and Jones, 1971).

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There have been a variety of procedures recommended by investigators to estimate the efficiency of the palatal lift appliance. These procedures have included clinical judgments of articulation and voice quality change in speech (Gibbons and Bloomer, 1958), measures of speech intelligibility using a closed-set modified rhyme test of words (Kipfmueller and Lang, 1972), lateral cephalometrics and oral manometric procedures (Marshall and Jones, 1971), combined nasal air flow and air pressure measures to determine velopharyngeal orifice area (Hardy et al., 1969; LaVelle and Hardy, 1979; Shaughnessy, Netsell and Farrage, 1983) and cineradiographic, acoustic, and perceptual measures of speech proficiency (Aten et al., 1984).

Our approach to the prosthetic management of patients with velopharyngeal incompetency follows guidelines suggested by Netsell and Daniel (1979) and Rosenbek and Netsell (1985). Basically, this approach involves evaluating the type of involvement and severity of each structure or set of structures (the "functional components") that operate to valve the air stream for speech purposes. This evaluation includes perceptual judgments and instrumental assessments of each component of the speech system. Perceptual evaluations such as those recommended by Rosenbek and LaPointe (1978), Darley, Aronson and Brown (1975), Johns and Salyer (1978), Yorkston and Beukelman (1984) and Enderby and Roworth (1985) provide details concerning articulation, voice production, resonance balance, intelligibility and strength, and movement and control of the articulator elements. The instrumental assessment may include spectrographic analysis of speech (Kent and Rosenbek, 1982), acoustic timing features of speech (Collins, Rosenbek and Wertz, 1983; Weismer, 1984), segmental organization of speech (Kent, 1983), aerodynamic assessment (Warren, 1982) including aspects of respiratory control (Hixon, 1982; Putnam and Hixon, 1984), laryngeal activity (Hirano, 1981), velopharyngeal action (Warren and DuBois, 1964) and articulatory efficiency (Warren, Nelson and Allen, 1980), videofluoroscopic or fiberoptic observations of speech articulator movements (Pigott and Makepeace, 1982; Miyazaki, Matsuya and Yamaoka, 1975; Williams and Eisenbach, 1981) and finally, structural movement, force and biometric (EMG) evaluations of the structural components for speech (Abbs, Gracco and Cole, 1984; Barlow and Abbs, 1983). While providing baseline information concerning the strength and/or weakness of each valve in the vocal tract, this practical approach allows for further understanding of why dysarthric talkers sound a particular way to the average listener. Continuing assessment using such an approach allows clinicians to note which behavioural therapy methods or prosthetic appliances are the most useful and what changes occur in other components when one valve has been altered.

The following information is intended to describe methods of assessment of prosthetic management and speech production for dysarthric patients with associated velopharyngeal incompetence.

MANAGEMENT OF PATIENTS

Diagnostic Procedures

Individuals seen in the Orofacial Rehabilitation Unit for an initial assessment are typically evaluated in midmorning to ensure higher levels of physical energy for the evaluation protocol. At this evaluation, both the speech pathologist and prosthodontist exchange information concerning the ability of each patient to benefit from a palatal lift appliance. The speech pathologist obtains information from hospital files, referral letters and the patient concerning the type of insult received, the time elapsed since the insult, a brief summary of the medical-behavioural treatment, and the social-emotional-psychometric constraints that may detract from successful prosthetic management.

A. Oral Examination

The speech pathologist and the prosthodontist also survey the anatomical structures of the oral cavity to ascertain any negative influences on speech that might occur with the placement of the palatal lift appliance. Clinical descriptions concerning the amount and speed of movement during speech and nonspeech tasks are reported. In addition, tissue deficiencies or asymmetries of the oral, velar, and pharyngeal structures are noted and recorded on an oral-peripheral speech evaluation form.

B. Evaluation of the Speech Production Mechanism

This examination begins at the foundation (respiration) and moves upward to include phonation, resonation and articulation (see Table 2 for an example with a patient).

RESPIRATION

The assessment of respiration is designed to estimate whether there is a sufficient amount of air available for phonation and production of speech. Observation of chest wall action during tidal (quiet, rest) breathing and speech allows for gross visual perception of the rate and excursion of the respiratory system. With patients who self-report or demonstrate respiratory irregularities, a more detailed evaluation employing respiratory kinematic techniques (Hixon and Putnam, 1983) or pulmonary function tests (Mead, 1979) is strongly recommended. When appropriate, the patient is asked to sustain phonation of the vowel /a/ or count for as long as possible after a maximum inhalation. Judgments of adequacy of breath support are made on a 7-point scale, with one (1) representing normal respiratory control, and the ability to sustain vowels for at least 15 seconds (adult) and/or the ability to count to 15 on one breath. A four (4) on the scale represents moderate impairment with the patient producing sustained phonation of about 7 seconds and being able to count to 7 on one breath. A seven (7) on the scale indicates severe impairment with the patient unable to sustain a vowel for 2 seconds or count to three on one breath.

Another technique for assessing respiratory support for phonation and speech is via measurement of subglottal air pressure. Using electronic instrumentation, subglottal air pressure (P_s) measures may be obtained (Leeper and Graves, 1984) from the pressure/flow traces (described in a later section) by measuring the peak intraoral air pressure output (as an estimate of alveolar air pressure) of voiceless /p/ consonant output, from a repeated string of /pi/ syllable productions. In essence, the air sensed behind the lips with a pitot tube is equivalent to the subglottal pressure since it represents a stagnant column of air trapped in the oral-pharyngeal-tracheal tube for the instant that the lips are approximated for the /p/ sound. We have also included a clinical subglottal pressure estimation procedure described previously by Netsell and Hixon (1978). During this procedure each patient is asked to produce (blow) a steady stream of oral air pressure through a custom-designed "leak" or T tube. In our system, a parallel oral air pressure sensing tube is connected to one lead of a differential pressure transducer, the signal is amplified and the output is then fed to one channel of an optical oscillograph. The patient performs a maximum sustained breath stream for three trials and the positive voltage displacements on the chart recorder paper are related to a calibration factor determined from an external pressure sensing device (U tube manometer). If electronic instrumentation is not available, pressure values may be read directly from the U tube manometer in millimeters (mm) of water displacement. This is accomplished by attaching one end of the rubber tubing to the U tube manometer and the other end to the "leak" tube which is then placed just distal to the patient's lips. Patients with excessive nasal air escape often overdrive the respiratory system to compensate for the loss of air at the velopharyngeal port. Netsell and Hison (1978) have suggested that patients with impaired velopharyngeal valving produce sustained breath tasks using the "leak" tube below the expected value (i.e., 5 cm H_2O for five seconds).

By gently pinching the nose closed or by using nose clips during these tasks, an estimation of the benefits of any prosthesis may be made prior to palatal lift placement. Differences in breath support with and without the nose closed may indicate the potential for improvement in respiratory control following placement of the lift.

PHONATION

Using a modified Voice Profile format (adapted from Wilson and Rice, 1977) (see Table 2 for an example), estimates of laryngeal function (open to closed), pitch, loudness, and vocal range are recorded on the profile form. Maximum phonation time (MPT) is also recorded with a stop watch during sustained vowel /a/ production. Other vocal features relating to the intonational contour are noted as normal or not normal. Use of the overall severity rating scale (1 to 7) provides an estimation of how the vocal function may affect overall speech production. It has been our experience that patients with (-3) laryngeal function of a severe degree (6 or 7 severity), poor intonational control of pitch and loudness, and MPTs of less than 3 seconds are generally not good candidates for palatal lifts because of inefficient vocal fold valving. Intervention via Teflon or collagen injection by the ENT physician may give the patient better vocal fold closure and place him/her in a more favorable category for palatal lift placement.

RESONATION

For the perceptual component of the evaluation, one portion of the Voice Profile (Wilson and Rice, 1977) (see Table 2 for an example) is used. Judgments of resonance balance are based upon production of high vowels /i/ and /u/ in isolation, syllable productions of high vowels and voiceless plosives (/p/, /t/, /k/), fricative (/s/, /ʃ/) and an affricative (/tʃ/) in sentential contexts. Using the definitions suggested by Wilson and Rice (1977), we have found that patients with (+3) and (+4) categories of resonance imbalance benefit most from palatal lift placement, particularly if the overall severity of the voice profile is (4) or higher. We also suggest that patients with adequate respiratory support and laryngeal valving and fair-good articulation skills are judged more favorably with the lift in place than are patients with poorer breath support, inefficient vocal fold closure and poor motor control of the articulators.

For the aeromechanical portion of the evaluation, each patient is brought to the Speech Physiology Laboratory, seated in a chair facing the instrumental array (Figure 1) and asked to perform specific speech tasks. A

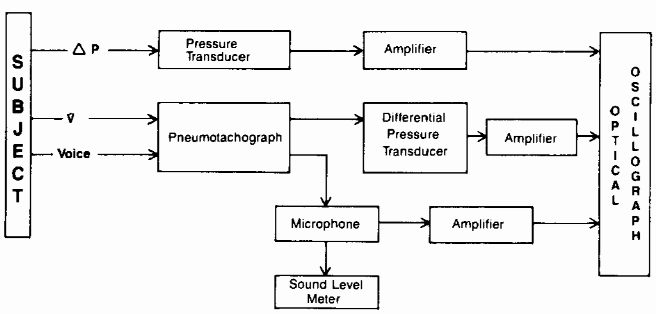

Figure 1. Instrumental Array for Assessment of Aerodynamic Characteristics of Speech

mask, firmly placed over the patient's nose, is attached to a pneumotachograph and associated differential pressure transducer. During speech, the analog signal from the pneumotachograph-pressure transducer is amplified and fed to one channel of the oscillographic recorder. A pressure sensing tube (catheter) is positioned behind the lips and one lead attached to one inlet valve of a differential pressure transducer. The second lead of the transducer is open to atmospheric pressure. Hence, the differential pressure is between oral-pharyngeal pressure and atmospheric pressure. Research in our laboratory (Allison and Leeper, 1985) has shown no statistical difference between the procedure detailed here and procedures employing oral and nasal airway-positioned differential pressure sensing tubes.

Productions of the vowel-consonant-vowel (VCV) syllables /ipi/ and /isi/, in groups of three, repeated at a rate of approximately 1.5 syllables per second, serve as syllable level material for this portion of the assessment. The connected speech samples used include the sentances "Say top for me papa" and "The man is sad and mean". Segmenting of the speech elements from the oscillographic tracings allows for direct analysis of differential air pressure and air flow necessary for estimations of velopharyngeal orifice area (Warren and DuBois, 1964) and calculations of nasal airway resistance (Warren, Trier and Bevin, 1974).

For estimations of velopharyngeal port size, a technique described by Warren and Dubois (1964) is employed as one form of analysis of the pressure/flow data. During the data collection component of the trials, differential air pressure and nasal air flow are recorded simultaneously. Measurement of pressure is made at the point of maximum peak amplitude for each consonant of interest. Air flow is determined by placing a perpendicular line from the maximum pressure amplitude and extending it upward to intercept the air flow trace for that consonant. The distance between these points in relation to the baseline is multiplied by an external calibration factor and is then used to calculate the estimated area of velopharyngeal size according to the Warren and DuBois (1964) formula:

$$\text{Orifice Area (mm}^2\text{)} = \frac{\dot{V}_n \text{ (Rate of Air Flow) (in cc/s)}}{k = (.0065)\sqrt{\dfrac{2\,\text{(Differential Air Pressure (980.3d/cm}^2 \times [\,\Delta p\,[\text{ in cmH}_2\text{O}))}{\text{Density of Air } (0.001 \text{ g/cm}^3)}}}$$

Warren and DuBois (1984) suggest that the k coefficient corrects for such factors as turbulence, non-uniform or rotational flow and provides a reasonable estimation of actual two-dimensional orifice size.

Evaluation of a number of patients has indicated that orifice area 25 mm^2 or greater place individuals in a category for management of the velopharyngeal port. Orifice sizes between 15 - 20 mm^2 show mild to moderate closure problems and those near 10 - 15 mm^2 represent borderline to mild problems as assessed during aerodynamic measurement of repeated syllables and sentence productions. We have also noted that when an estimated opening of less than 12 - 15 mm^2 occurs during nasal consonant /m/, /n/ production, listeners may detect hyponasality (-2 on the Voice Profile) in the patient's speech. These values are also consistent with Warren's (1982) reports for estimated orifice areas of cleft palate patients with velopharyngeal incompetency. Likewise, when considering average nasal air flow and oral air pressure (Thompson and

Hixon, 1979; Warren, 1982), flow values that exceed 250 - 300 cubic centimeters per second (cc/sec) and air pressures which fall between 4-5 cmH_2O for voiceless plosives, fricatives and affricatives in syllable and sentence contexts, suggest that the patient is in need of direct management. Borderline cases, those individuals with nasal air flows between 75-150 cc/sec and air pressure values for voiceless consonants below 3-5 cmH_2O with only fair articulatory precision, are also in need of prosthetic aid to improve velopharyngeal competency.

As another aid to evaluating velopharyngeal function and nasal airway competency, we routinely assess resistance to air flow through the nose. Nasal airway resistance measurements reflect a ratio of instantaneous air pressure and air flow at some point in time when the air flow passes through the velopharyngeal port and the nasal passages. The values obtained reflect the resistance to air flow afforded by the combined effects of velar position, nasal anatomy and the palatal lift prosthesis during vegetative (rest) breathing and sustained /m/ production.

We employ the same instrumental array for nasal airway resistance measures (Figure 1), as we reported earlier for the assessment of velopharyngeal orifice area. Each patient is fitted with a nasal mask which is attached to a pneumotachograph, differential pressure transducer and amplifier. The voltage analog signal of nasal flow is led to one channel of an optical oscillograph and is used to represent nasal air flow. A pressure sensing catheter attached to one inlet valve of another pressure transducer amplifier system is led to a separate channel of the oscillograph. This system is used to record oral air pressure collected by the catheter positioned behind the lips of the patient during tidal breathing or sustained /m/ production. Such a technique for estimation of nasal airway resistance is supported by the research of Allison and Leeper (1985). During the procedure, each patient is asked to produce five cycles (inhalation/exhalation) of vegetative breathing and then to produce three sustained /m/ productions for at least three seconds each. Simultaneous measurements of air pressure and air flow at flow rates of 125, 250 and/or 500cc/sec are used to calculate nasal airway resistance ($Rn=\Delta p \div \dot{V}n$). Since resistance values are flow dependent, we have chosen values that may be produced by the patient, that fall below estimated values for turbulent flow, and yet may be compared to research data already available in the nasal physiology literature. For patients with severe respiratory control problems, we choose the lower air flow values during the airflow maneuver for measurement. Visual monitoring of the air flow rate via an oscillographic analog estimation of the desired level (i.e., 125 cc/s) has also been used with some subjects. The production of the sustained /m/ phoneme has been a very useful method for obtaining nasal resistance measures for patients with severe neurological involvement.

It has been our experience that nasal airway resistances in the dysarthric subjects fall within the range of 1.2 to 13.2 cmH_2O/LPS. Increases in nasal airway resistance by at least 2-4cmH_2O/LPS occur with the placement of a palatal lift appliance. Such resistance measures are useful in the modification of the appliance since too much constriction will cause nasal congestion problems leading to possible infection sites in the nasopharynx and middle ear cavity. This overclosure may also lead to mouth breathing and open jaw postures. This condition may also enhance the perception of hyponasality on nasal consonants and surrounding vowels by listeners. High resistance values and the consequences of large airway obstructions to air flow in the nasal passages are in accordance with reports by Warren, Trier and Bevin (1974).

ARTICULATION

The assesment of the articulatory component of our dysarthric speakers is accomplished by employing formal and informal tests (i.e., Templin-Darley Tests of Articulation, syllable repetition). Particular interest is given to high pressure consonant (plosives, fricatives, affricatives) production in high vowel /i/, /u/ environments in syllables (CVC, VCV) and in short sentences "loaded" with high vowels and high pressure consonants. We have found that such contexts demand the most constricted and consistent velopharyngeal approximation, thus putting a "load" on the potentially incompetent velopharyngeal system seen in the dysarthric patient (Moore and Sommers, 1973). Judgments of articulatory precision, speed of production, consistency of production and stimulability for behavioural change are also noted. In addition, any compensatory articulation adjustments habitually used by the patient since the insult, which could influence palatal design, are recorded under the comments section of the evaluation form. As a global description of articulation performance (see Table 2 as an example), we rate proficiency on a 7-point equal-appearing interval scale. On this scale one (1) represents normal articulation performance and a four (4) represents a moderate articulation disturbance affecting precision, speed and consistency of production. A seven (7) represents a severe articulation disturbance with weak or absent plosion of air, restricted articulatory speed and control, and with sound production expressed by neutral vowel and vowel-like sound classes.

For the aeromechanical portion of the assessment, the patient is asked to perform a task that will allow us to estimate the orifice area (size) and duration of the oral port constriction during fricative /s,z,f,v/ consonant production in syllable (CVC) contexts. While adequate closure of the velopharyngeal port is typically considered as one of the clinician's primary concerns with dysarthric individuals being considered for a palatal lift appliance, size and duration of the oral port constriction is of additional concern for physical assessment of factors related to intelligibility of speech. For patients with velopharyngeal closure problems, fricative consonants are often in error and are typically associated with larger oral port size and correlate well with a substantial loss in speech intelligibility (Claypoole, Warren and Bradley, 1974).

During the typical assessment, the patient is fitted with an oral mask and positioned in front of the instrumental array. This array is designed to record aerodynamic and durational data concerning oral port constriction following guidelines reported by Warren and Mackler (1968), Smith, Allen, Warren and Hall (1978) and Warren, Nelson and Allen (1980).

Oral port size is defined as the opening formed by the complex interaction of the oral articulators during fricative sound producion, while duration is the time involved in the production of the constriction for the fricative element. The placement of one catheter in the oral cavity behind the point of constriction and another in the mask in front of the oral constriction provides a record of differential air pressure across the oral port. The air pressure is recorded, filtered and amplified, and the resultant signal led to one channel of the chart recorder. Oral air flow through the constriction is obtained with a face mask placed around the lips and attached to a pneumotachograph-pressure transducer system. The voltage analog flow signal is amplified and led to another channel of an optical oscillograph. An orifice area equation (Warren and DuBois, 1964) is used to calculate oral port size from the air flow and air pressure measurements. This is the same equation used to calculate velopharyngeal orifice size, with the qualification that, in this situation, the air flow is oral and differential air pressure is the difference between the pressure measured with a catheter placed in the oral cavity behind the consonant constriction and the pressure in front of the constriction recorded from the catheter in the face mask.

Each patient produces a series of symmetrical (CVC) syllables containing the phonemes /s/, /z/, /f/, /v/ and the vowels /i/, /a/, /u/, with a carrier phrase "Say ______ again"; e.g., "Say *SuS* again". These syllables are produced at a conversational rate of approximately 1.5 per second or as close to this rate as the patient is capable of producing.

Duration of oral port constriction is determined by measuring the time for the initial rise of pressure from baseline (representing the closing of the constriction), to the point of release of pressure (marking the opening of the constriction). This definition corresponds to the time when the lips and teeth are in close approximation for /f/ and /v/ or when the tongue approximates the alveolar ridge for /s/ and /z/ productions.

Examination of data from the dysarthric patients seen in our clinic suggest that average oral orifice size values range between 14-18mm^2 for /s/ and /z/ contexts and from 20-25mm^2 for /f/ and /v/ contexts without a palatal lift in place. After palatal lift fitting, oral orifice areas for /s/ and /z/ are generally reduced by 3-4mm^2 and by about 2mm^2 for /f/ and /v/. While individual patients vary in oral port size, more velopharyngeally incompetent patients show larger oral port openings and subsequent articulation difficulties. In general, oral orifice sizes between 10-20mm^2 occur when articulation is mildly-moderately impaired, while openings over 20mm^2 suggest moderate to severe opening problems. A number of variables, such as dental occlusion, and differential impairment of lips, tongue and jaw, must be considered before oral orifice size values are labelled as "outside normal limits". The oral orifice size values presented in the paper are probably best used to correlate with perceptual changes in articulation performance following prosthetic management.

Duration of oral port constriction should likewise be considered as a relative value as opposed to an absolute value. That is, we have found that patients increase the duration of oral port constriction from pre-management to post-palatal lift management by about 30 milliseconds (e.g., from 160 to 192 milliseconds for /s/ contexts). Variablility also increases by about the same ratio. This suggests that patients are increasing the time spent in articulating the speech sounds following lift management. Such changes may be noted in articulation testing or in analysis of speaking rate as it relates to overall intelligibility (as with the *Computerized Assessment of Intelligibility of Dysarthric Speech (C.A.I.D.S.)* analysis by Yorkston and Beukelman, 1984).

SPEECH RATE ASSESSMENT

The reduction of speaking rate of dysarthric speakers is a well known phenomenon and has been described by several investigators (Darley, Aronson and Brown, 1975; McNeil, Rosenbek and Aronson, 1984). For our prosthetically managed patients, rate of speaking in sentences serves as one of the methods for temporal analysis of speech. During the speech assessment, tape recordings of 13 sentences (Van Demark, 1964) are recorded on magnetic tape and these recordings are led to a power level recorder for acoustical analog voltage displays of the spoken text over time. Word per minute (wpm) and syllable per second (sps) rates are then calculated for each patient for each management condition by marking the beginning and end of the speech samples and converting millimeter distance to time measurements in milliseconds. Total average sentence duration, phonation time and pause time ratios are obtained and compared to values from the research literature (Lass and Noll, 1970). Similar durational assessments are also made using a short segment (3 minutes) of the patient's spontaneous speech sample. This information, in conjunction with the duration of oral port constriction, form our data base and provide temporal data at the syllable, word and sentence levels of production.

From an overview of our patients' records, the average speaking rate is about 100 words per minute (wpm) (1.90 syllables per second). The range is quite variable, ranging from 35 wpm to 187 wpm. With normal subjects, speaking rates average about 220 wpm, with a range of 190 to 253 wpm being appropriate. Likewise, sps rates are two to three times faster (4 - 6 sps) for normal speakers than for the patients we have seen (Lass and Noll, 1970). Generally, we have seen a slight reduction in rate of production following palatal lift placement. Thus, the neurological damage sustained by these patients is apparently of far greater significance to rate of speaking than is the lack of velopharyngeal closure. With the slight decrease in overall phrasal speaking rate and the increase in closure duration for voiceless consonant elements, we suggest that our patients are increasing durations of speech sound elements in syllable or larger contexts in order to enhance overall speech intelligibility. Such assumptions are consistent with a multi-level speech motor control model discussed by Netsell (1982) for dysarthric speakers. A recent commercially available package for estimating rate of intelligible speech for dysarthric patients via microcomputer analysis (*C.A.I.D.S.*, Yorkston and Beukelman, 1984) is also recommended.

Radiographic Evaluation of the Velopharyngeal Port

As part of our assessment within the hospital environment, we routinely evaluate lateral cephalometric X-rays to determine the physical two-dimensional activities of the oral-pharyngeal mechanism. Cephalometric radiographs are taken of the patient in the traditional rest position and during quasi-steady state productions of the /u/ and /s/ phonemes.

Lateral cephalometric X-rays of velopharyngeal action in a mid-saggital plane are used to describe measures of velar length, velar thickness, pharyngeal depth, velopharyngeal gap, velar "stretch" and the "need ratio" of each patient. Normative values for each of these measures may be found in the research of Simpson and Austin (1972), Simpson and Colton (1980) and Simpson and Chin (1981). While static two-dimensional views via lateral cephalometry have definite limitations in the assessment of the three-dimensional characteristics of the velopharyngeal port (Williams and Eisenbach, 1981), it is a tool which is available to most speech pathologists, even in smaller medical or rehabilitation settings. Lateral cephalometry is one of several methods of radiologic assessment which allows for the evaluation of features we have found important in noting change in the velopharyngeal component of the speech system: namely, velar length, gap, and velar stretch, both prior to and following palatal lift insertion. Cephalometry is also a technique that is used by other dental specialties, such as orthodontics, to evaluate facial growth, facial re-alignment or tooth movement during the period of prosthetic management. To this extent, professional colleagues in a hospital or rehabilitation unit may take one set of X-rays that may satisfy several assessment needs.

Our evaluation of patients suggests that X-ray measures of "gap" (the distance between the most posterior part of the velum and the posterior pharyngeal wall) range between 1.0 and 14.0mm distance for the rest position, and for /u/ and /s/ production for most patients' pre-lift insertion. Gaps from .5mm and 1.5mm may be seen post-insertion. This amount of gap allows air to pass through the nose for aeration of the nasal membranes.

Another important factor for the dysarthric patient is the amount of "stretch" (the increase in intrinsic length of the velum during phonatory activity compared to the length at rest). We have noted that there is a "stretch" increase of about 6mm in length for /u/ and 5mm for /s/ production for post-insertion lift activity. While normal subjects may show an increase of as much as 28% (Simpson and Austin, 1972), dysarthric subjects show an increase of only 8% (Sills and Leeper, 1984). The increase in the "stretch factor" following prosthetic management appears to be of clinical significance in effecting improvement in the action of the velopharyngeal valve.

Evaluations of Intelligibility and Resonance Balance

Intelligibility tests provide a necessary component to relate a listener's subjective judgments of speech performance to physical measures of aerodynamic and acoustic characteristics of speech. Continued monitoring of the speaker's performance during the course of prosthetic management gives an indication of the effectiveness of the palatal lift.

Each patient seen for a palatal lift prosthesis is assessed with a 50-item word list developed by Tikofsky (1970) to provide a short, clinically useful tool for estimating single-word intelligibility for dysarthric speakers. This particular test contains consonant-syllable nucleus-consonant (CNC) syllables, consonant clusters in either initial or final position and spondaic (two-syllable words. The 50-word test has been compared with longer intelligibility tests and found comparable to the other intelligibility measures (Yorkston and Beukelman, 1982).

Unsophisticated listeners from the hospital or beginning students at the university are presented with randomized orderings of the word lists for judgments of pre and post-management intelligibility. Transcriptions of each word produced by the speakers are written on a scoring sheet. The number of words correctly identified by the listeners from the 50-word list is then used to represent the patient's overall intelligibility score. Since the initiation of our assessment procedures, other intelligibility measures have become available for use and the analysis may now be done via microcomputer (e.g., *C.A.I.D.S.*, Yorkston and Beukelman, 1984). We have recently modified our assessment protocol to follow these developments.

For more contextual examples of the patient's speech, listeners are also asked to rate each of 13 sentences (Van Denmark, 1964) for estimates of overall speech intelligibility using a seven-point equal-appearing interval scale. With this measure, a one (1) represents completely intelligibile speech, four (4) represents moderately unintelligible speech, and seven (7) represents non-intelligible speech. In addition, a clinical estimation of whole-word articulation accuracy is recorded from the Templin-Darley Tests of Articulation (Templin and Darley, 1969).

For judgments of hypernasality, a separate group of listeners are asked to judge the degree of severity of resonance balance from each of 13 sentences (Van Demark, 1964). Again, a seven-point equal-appearing interval scale is used for the evaluation. On this scale one (1) represents normal resonance balance (no excessive hypernasality), four (4) represents moderate hypernasality, and seven (7) represents severe hypernasality.

For pre- and post-lift management conditions, the scores from each listener's rating of the speech samples are averaged to obtain a mean of the scale values for all listeners on measures of intelligibility, whole-word articulation precision, and hypernasality.

Prosthodontic Assessment

Following the initial observations by the speech pathologist, the prosthodontist completes careful records of oral and dental health. Full mouth X-rays and panorex films are made to document the health, structure and dental relationships of these patients. Since some patients have suffered traumatic injury or have been in intensive care for some extended period of time, the current dental hygiene and oral health is of first importance. Necessary restorations and prophylaxis are completed in order to prepare the patient for dental impressions and the fitting of the appliance. Next, the prosthodontist takes irreversible hydrocolloid impressions of both the maxillary and mandibular arches. Diagnostic casts are recovered from the impressions in order to aid in the construction of the palatal lift appliance. A survey analysis of the diagnostic maxillary cast is then performed and a comprehensive treatment plan is formulated by the prosthodontist. A detailed list of dental considerations and guidelines for prognosis of success for the patients that we typically treat may be seen in Table 1.

Design of Palatal Lift Prosthesis

With both the dentulous and partially edentulous patients, the design of the lift prosthesis must rigidly adhere to the basic principles of removable partial denture design. It is essential to incorporate the component functions of retention, support and bracing in the appliance. It is also important to ensure uniform distribution of stress around strategically located major dental abutments and to have placement (lifting) of the involved palatal tissues in a functional rather than an anatomic form. To ensure strength, the components of the palatal lift are cast in chromium cobalt alloy as a one-piece casting. The lift portion of the prosthesis is constructed of clear acrylic resin base to facilitate modifications and adjustments.

Once the design of the appliance has been determined, tooth preparations are performed on the major abutment teeth, final impressions are made and master casts recovered from the impression. Master casts are forwarded to the dental laboratory for construction of the framework.

Patient Preparation and Framework Fabrication

Upon receipt of the framework from the dental laboratory, the framework fit is verified with an appropriate liquid disclosing solution. The lift impression is made by using a low fusing thermoplastic compound with the soft palate tissue elevated to make contact with the posterior pharyngeal wall. The impression is extended and modified according to the degree of lift of the palatal tissues required. This modification is based upon the objective clinical evaluation of speech and upon the aeromechanical records obtained from the patient. When a desirable amount of velopharyngeal competency is achieved, the tissue surface of the thermoplastic compound is reduced .5 to 1 mm. Impression wax is then painted over the tissue bearing surface and the lateral borders of the lift impression to a depth of 1 to 1.5 mm and seated in position for 6 to 8 minutes (Figure 2).

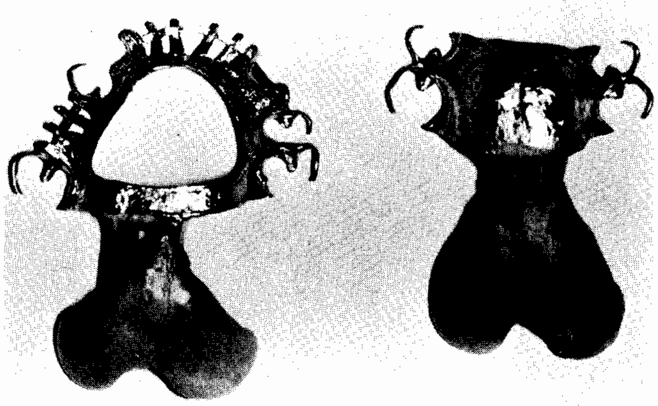

Figure 2. Representation of Two Palatal Lift Prostheses with Impression Wax Painted on the Posterior-Superior Surface of the Lift to Note Tissue Bearing Pressures

Evaluation of Impression of Lift Portion

The speech pathologist and prosthodontist operate together to evaluate the effectiveness of the palatal lift. During this fitting period, the lift base configuration is influenced by: 1) the depth of the oropharynx, 2) the width of the posterior pharyngeal tissue, 3) the extent of the lateral pharyngeal wall port openings, 4) the degree of palatal and pharyngeal structure movement during sustained phoneme production, and 5) the presence of an excessive gag reflex. The prosthodontist must observe physiological constraints in tissue displacement during fitting, while the speech pathologist is interested in obtaining the best resonance balance possible.

While in the dental operatory with the patient, the speech pathologist aids in the fitting by making perceptual judgments of resonance balance of isolated sustained vowels /i/ and /u/ in contrast to /a/ and in conjunction with CVC or VCV syllables containing voiceless plosives, fricatives and affricatives. Nasal air emission is noted by the presence of "fogging" of a cold mirror held under each side of the nose during high vowel or CVC, VCV syllable productions. The amount of nasal air pressure present is also noted with the use of a U tube manometer with rubber tubing connected to one leg of the U tube system with nasal olives attached to the free end and placed against one nostril.

Although the lift is designed to increase velopharyngeal closure capability, there must be sufficient nasal airway patency to permit nasal breathing as well as production of nasal consonants. With the lift in place, the patient produces a sustained /m/ or repetitions of /mʌmʌ/.

If nasal sounds become oralized (i.e., /b/ m and/ d/n/), the prosthodontist makes the necessary corrections by shaving the compound and reapplying the impression wax to indicate the evenness of reduction around the palatopharyngeal region.

After evaluation and correction, the completed impression is recovered and converted to heat polymerized clear acrylic resin (Figure 3).

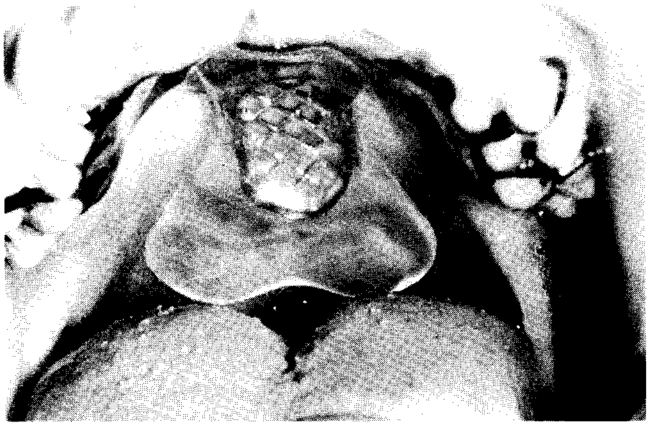

Figure 3. Picture of the Posterior Lift Portion of the Prosthesis Converted to Polymerized Clear Acrylic and Placed in Position in a Patient's Mouth

Delivery Stage

The patient is instructed to wear the prosthesis as much as possible, excluding mealtime and bedtime, during the first few days after insertion. The patient is encouraged to increase the tolerance for wearing the prosthesis during drinking and eating. Each person is told how to care for the prosthesis, how to place it and remove it, and is reminded to contact the prosthodontist if there are any changes in clasp retention or tissue irritation following a period of wear.

Following modification and conversion of the newly-formed lift portion of the prosthesis, the patient is seen again in the laboratory for complete speech reassessment.

Case Presentation

To better illustrate decisions regarding placement and continued management of patients with a palatal lift appliance, information regarding a dysarthric patient wearing an appliance for speech purposes is presented.

Laryngeal Cavity — Pitch: High, +3, +2, (2), 1, -2, -3, Low; open -4 -3 (2) 1 +2 +3 closed

Resonating Cavity — Nasality: Hypernasal, (+4), +3, +2, 1, -2, Hyponasal

Intensity: (2) 1 +2; soft — loud

Vocal Range: -2 (1) +2; monotone — variable pitch

(Overall Severity: 1 2 3 4 5 0 6 7)

(adapted from Wilson and Rice, 1977)

Respiration: 1 2 3 (4) 5 6 7 (Severity)

a) MPT — /a/: $\bar{X}$ = 7, S.D. = 1.5 sec.

b) Estimated P_s: $\bar{X}$ = 6.0 cmH_2O, S.D. = .8 cmH_2O

c) Comments: *slight difficulty maintaining loudness — phrasing.*

Phonation: 1 2 (3) 4 5 6 7 (Severity)

a) Profile: (see above Voice Profile)

b) Comments: *restricted loudness level*

Resonation: 1 2 3 4 (5) 6 7 (Severity)

a) Profile: (see above Voice Profile)

b) Comments: *nasal air emission — pressure consonants.*

Articulation: 1 2 3 4 (5) 6 7 (Severity)

a) Comments: (precision, consistency, speed, other) ____
weak articulation, slightly slow production, consistent consonants errors, some imprecision in syllables and in context

Table 2: Voice Profile and Speech Assessment Form for the Selected Patient Prior to Palatal Lift Placement

Table 1: Management Consideration for Prosthodontic Care

Diagnostic and Treatment Planning Factors	PROSTHODONTIC ASSESSMENT Treatment Considerations	Prognosis
1. Dental status of the patient.	1. a) All restorative, peridontal and related dental procedures must be completed prior to the commencement of prosthetic procedures. b) The patient must be educated in the necessity of periodic recall appointments.	1. Prognosis will be favourable if the patient maintains a high standard of oral hygiene and dental health.
2. Design of the prosthesis.	2. a) Most palatal lift prostheses will consist of three sections: the maxillary section or body, the palatal section or tailpiece and the lift section. b) For permanent lifts, the maxillary and palatal section can be cast as one-unit framework in chromium-cobalt alloy. The lift portion of prosthesis is constructed of clear acrylic resin base attached to the palatal section. This material permits adjustment, modification or replacement as indicated by periodic assessment. c) For temporary lifts, the prosthesis can be constructed of acrylic resin base retained by wrought wire clasps on key abutment teeth.	2. a) The accuracy and stability provided by the permanent prosthesis will guarantee a more favourable prognosis thatn the temporary lift. b) The temporary prosthesis is not as stable and requires more bulk, can be easily distorted and is more prone to cause tissue irritation.
3. Design of the anterior section of the prosthesis.	3. a) The anterior section must possess supporting, bracing and retentive elements. b) Suitable major abutment teeth must be strategically located to provide supporting and retentive functions and ensure uniform distribution of stress to hard and soft tissues during elevation of the palatal tissues.	3. a) A good prognosis can be anticipated if the components of the framework are designed and located to resist the forces incurred by oral function. b) With palatal lifts, cast retentive arms will resist dislodging forces more favourably than wrought wire retentive arms.
4. Occlusal relationships of the remaining natural dentition.	4. The major abutment teeth must be clinically prepared to receive the components of the maxillary section.	4. a) Prognosis will be favourable if the natural teeth have normal tooth-in-tooth contact upon closure and in functional positions. b) Inadequate or no preparation may cause metal tooth-to-tooth contact upon closure encouraging trauma to the supporting and/or opposing dentition with positive Temporo-mandibular joint symptoms.
5. Contour of the major abutment teeth.	5. Natural tooth undercuts must exist on major abutment teeth to retain the prosthesis in place.	5. If undercut areas are lacking on major abutment teeth, undercut areas must be prepared and/or created by restorations to ensure a successful prognosis.
6. Contour and depth of the palatal vault area.	6. a) If normal in contour a palatal strap (bracing element) should be considered. The connector should extend from natural teeth on one side to natural teeth on the other across the mid-palatal area, located posterior to maxillary anterior teeth and rugae area and	6. Prognosis will be satisfactory if: a) The connector is rigid enough to provide cross-arch stabilization and yet thin enough to minimize tongue interference.

Table 1: Management Considerations for Prosthodontic Care

Diagnostic and Treatment Planning Factors	PROSTHODONTIC ASSESSMENT Treatment Considerations	Prognosis
	slightly anterior to the junction of the hard of the hard and soft palates. b) A closed oral connector (no metal coverage in the mid-palatal area) should be considered where: i. the palatal area is deep, narrow and V-shaped ii. contour of the palatal tissues is irregular iii. a well-defined median palatine suture or maxillary torus is present iv. the length of the hard palate area is extensive antero-posteriorily; and v. mandibular anterior teeth are present.	b) Design must be symmetrical and single to be accommodated by tongue and tissues.
7. Type of pharyngeal form and resistance to displacement of soft palate area.	7. Treatment considerations are influenced by: a) The flaccidity versus the spasticity of the palatal-pharyngeal area. b) The lateral pharyngeal wall action. c) The uvular action. d) The size and form — i.e., narrow posterior pharyngeal area versus the wide open area.	7. a) A more favourable prognosis can be anticipated when: i. the palatal-pharyngeal area is more flaccid; and, ii. the lateral pharyngeal wall action is pronounced, the action closes down toward the lift component. b) A less favourable prognosis is expected when: i. there is very active uvular movement. Strict attention must be paid to the contour and extent of the posterior border and tissue surface of the lift and the degree and location of retentive elements in the maxillary section.
8. The estimated length and width from the anterior border of the soft palate to the posterior pharyngeal wall.	8. The design of palatal extension is dependent upon the width and length of the palatal area to be elevated: a) where there is minimal lateral pharyngeal wall and sufficient soft palate length exists, a cast half round loop is extended posteriorly from the midline area of the posterior border of the maxillary section. The loop extends posterolaterally on both sides, along the palatal plane to within 2 mms of the palatal area to be lifted and 3mms anterior to musculus uvulus. b) If the patient limited width and/or length, then a notched cast metal extension is extended posteriorly along the palatal plane to within 3mms of the musculus uvulus.	8. With either situation an acceptable prognosis can generally be anticipated. However, if the musculus uvulus activity is pronounced; the retentive capabilities of the palatal extension may be lessened to a degree where the prognosis may be unfavourable.
9. The estimated degree and symmetry of the neuromuscular activity of the velum.	9. The extent and contour of the posterior border of the acrylic resin lift must accommodate and harmonize with the activity of the velum.	9. In some cases, failure to trough the tissue surface of the lift in accordance with velum activity will result in an unfavourable prognosis. The more active the velum is the less favourable the prognosis.
10. The amount and consistency of saliva.	10. Patients with salivary problems may have a limited prognosis. They should be encouraged to rinse the prosthesis and oral cavity separately several times daily. b) Patients presenting thick ropy saliva may encounter	10. a) Patients with some types of neurological disorders or brain stem damage often present the problem of excess drooling with or without the lift in place.

Table 1: Management Considerations for Prosthodontic Care

Diagnostic and Treatment Planning Factors	PROSTHODONTIC ASSESSMENT Treatment Considerations	Prognosis
	difficulty in retaining the lift in place after a period of time. The saliva tends to accumulate on the tissue surface of the lift, interfering with normal palatal contact.	
11. The degree of gag reflex present.	11. a) Generally speaking most patients with velopharyngeal incompetency present very little gag reflex. b) The most common "gaggers" are found in patients presenting a high narrow palatal vault, sharply descending short soft palatal area, large bulbous tongue and/or extremely active musculus uvulus.	11. a) If not controlled, gaggers present a very unfavourable prognosis. b) These patients must be subjected to a comprehensive palatal desensitization program for one month prior to commencement of treatment (breathing and finger massage exercises).
12. The size, shape, position, symmetry and range of mobility of tongue.	12. The palatal contour of the lift, the design and thickness of the anterior section must accommodate the functional range of the tongue.	12. The prognosis is less favourable where the tongue is very active and with patients presenting sharply decending and short/ soft palate areas.
13. Manual dexterity of the patient.	13. Patients and support personnel must be instructed and thoroughly knowledgeable in the methods of insertion and removal of the prosthesis.	13. Prognosis is unfavourable where patients do not accept these responsibilities or have limited manual dexterity.
14. Patient's attitudes and cognitive abilities.	14. Patients should be educated in: a) The role and limitatins of the prosthesis. b) The initial tolerance problems. c) The care and maintenance of the prosthesis.	14. The prognosis is based upon the compliance of the patient to accept his/her role in functions, limitations and care of the prosthesis.

The illustrative patient is a 23-year-old male suffering from head trauma obtained in a motor vehicle accident. The patient presented with moderate left hemiplegia. He was referred for prosthetic assessment 6 months post onset following admission to a hospital day care program for brain-injured young adults.The patient exhibited unimpaired language as noted from reported results of the Western Aphasia Battery (WAB) (Kertesz and Poole, 1974). Hearing was within normal limits bilaterally as noted from a hearing screening examination at 20 dB HTL.

The speech examination was performed during the initial visit to the Orofacial Rehabilitation Unit. An examination of oral structures revealed a slight deviation of lip mobility on the left for protrusion/retraction. Pucker and swing and smiling repetition rates were approximately 1.0 per second. The patient could protrude the tongue, although it deviated slightly to the left. Lateralization of the tongue and repetitions of /t/ occurred at a rate of 1.5 per second. The anterior dental relationships showed a mild open bite in the anterior left quadrant from the left central incisor to the first premolar. A panorex view of the maxilla and mandible supported a known fracture of the anterior facial region as a result of the traumatic accident. The open bite represented only a mild hazard to speech, particularly for sibilant distortions. Mandibular rate of opening and closing was at a rate of 1 per second. Intraoral structures presented no hazard to speech production. Velar length appeared adequate for closure, with levator insertion appearing in the middle 1/3 of the soft palate. A slight asymmetry occurred with greater lift on the right side, but with velar mobility rated as only fair bilaterally. Lateral pharyngeal wall activity was also rated as fair. No deviations were apparent from cursory examination of the nasal passages.

The results of the perceptual evaluation of speech production may be seen on the screening form (Table 2) which describes the speech characteristics related to the areas of respiration, phonation, resonation and articulation.

Respiratory activity was rated as 4, with mild difficulties in altering loudness and phrasing. Maximum phonation time was recorded at 7 seconds and estimated subglottic pressure was 6.0 cmH_20. Phonation assessment indicated a slightly breathy voice (-2) quality, with normal pitch and slight loudness difficulties (-2) and with a slightly restricted pitch range (1). Phonation severity was rated as 3. The resonance assessment indicated nasal air emission on vowels and consonants (+4, Voice Profile) with accompanying hypernasal quality rated as 5 on the severity scale. Articulation skills were rated as 5 on the severity scale, with fair-good movement of the tongue and slightly reduced speed for lingua-alveolar sounds and with slightly reduced air pressure and flow characteristics for pressure consonants such as plosives, fricatives and affricatives. Overall Voice Profile severity was rated a 5.5 by a panel of listeners for the parameters evaluated.

A physiological assessment of aeromechanical features was performed prior to placement of the palatal lift prosthesis. Figure 4 illustrates aerodynamic and acoustic

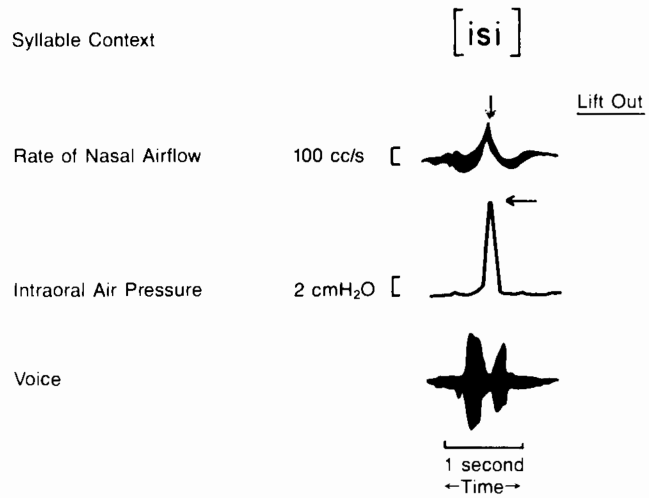

Figure 4. Example of a Patient Record for Syllable [isi] Production Without the Lift in Place

representations of the syllable [isi] as produced by the patient. The arrows indicate the peak pressure and air flow at a specific time in the speech utterance. Values derived at these points are used to calculate estimated velopharyngeal orifice size values using the Warren and DuBois (1964) equations. The nasal air flow for this patient was 280cc/s and the differential air pressure was 7.5 cmH_2O with an estimated orifice area of $16mm^2$. Separate measurements of nasal airway resistance for vegetative breathing was 5 cmH_2O/LPS ($\dot{V}n$=250cc/s, Δp=1.25 cmH_2O) and for sustained /m/ production the value was 6 cmH_2O/LPS ($\dot{V}n$=125cc/s, Δp=.75 cm H_2O). Closure duration measures of VCV syllables for this patient averaged 161.0 milliseconds. Rate of production in wpm and sps was 125 and 1.85 respectively. Lateral cephalometric X-ray data indicated a gap of 10.5mm at rest and a 6mm gap for /u/ production and a 4.5mm gap for sustained /s/ production. The stretch factor for /u/ was 7% and for /s/ it was 8.5%.

From the perceptual, aeromechanical and acoustic data collected with this patient, an overall level of functioning would place him within the mild to moderate range of severity for each level of the speech production system. He was deemed an appropriate candidate for the lift appliance and was treated following the guidelines noted earlier.

Following the placement of the palatal lift and its final fitting, the patient demonstrated improvement in both perceptual and physical measures related to velopharyngeal closure. Perceptually, the young man showed slightly improved respiratory support (-3), with improved loudness and phrasing maximum phonation times of 11 seconds and an estimated subglottal pressure of 7.0 cmH_2O. Phonation revealed little change, with a breathy voice (-2) and restricted pitch range remaining. Severity rating remained at a 3 value. The resonance assessment revealed a (+3) on the Voice Profile, with some hypernasality present on vowels and voiced consonants and with an overall severity rating of 3. Articulatory speed and precision remained fairly constant, but nasal air emission was eliminated from the plosive, fricative and affricative elements upon testing. Subjectively, air pressure and flow features of consonant production improved and severity was rated as a 3. Motor control of oral articulatory function remained mildly impaired. Overall severity of the Voice Profile was rated as 3 on the perceptual parameters.

A physiological assessment post-lift placement showed improved aeromechanical, acoustic and X-ray data during speech. As shown in Figure 5, air flow rate on

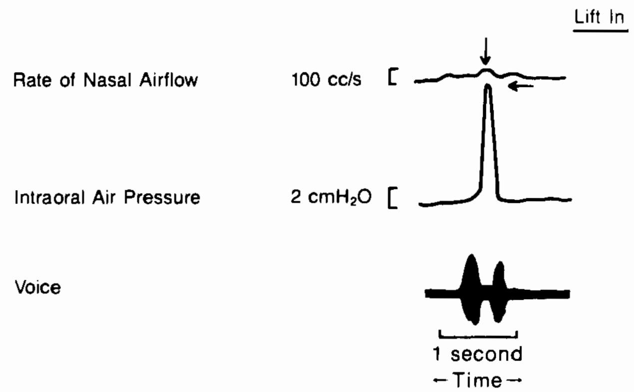

Figure 5. Example of a Patient Record for Syllable [isi] Production With the Lift in Place

syllable [isi] production was reduced to 40cc/s, with differential air pressure recorded at 9.5 cmH_2O representing an estimated orifice area of $2.0mm^2$. Nasal airway resistance for vegetative breathing ($\dot{V}_n$=250cc/s, Δp=2.4 cmH_2O/LPS/ and was 8 cmH_2O/LPS ($\dot{V}_n$=125cc/s, Δp=1.0 cmH_2O). Closure duration increased, on average, to 214 milliseconds for VCV syllable productions. Speech rate increased only slightly (by 10 wpm) with the lift in place. Lateral cephalometric information attained with the lift in position showed a reduction in gap to approximately 1.0mm and 0.5mm for /u/ and /s/ productions. The stretch factor was 13% for the /u/ and /s/ phonemes during production.

The data presented for this patient represent positive changes primarily related to the velopharyngeal valve. Secondary gains in respiratory and overall articulatory characteristics were noted. Certainly, speech management following palatal lift placement is warranted for this individual. In addition, counselling regarding the timing of various aspects of speech and dental management are an ongoing process. In our experience, such counselling should continue until the patient learns to separate, cognitively, the various components of speech (nasalization, hypernasality, oral air pressure) that will improve solely with the placement of the palatal lift. The patient also needs to be made aware of those aspects of speech (articulation precision, rate, vocal quality) that will benefit from continuing behavioural speech management. Prosthodontically, the patient must maintain good oral hygiene, attend to maintenance of the appliance, and develop a sensitivity to the speech changes related to the anterior and posterior aspects of the appliance.

Speech Followup

Since many of the patients seen in our Orofacial Rehabilitation Unit are referred solely for prosthetic management, they typically return to the "home" hospital or referring Speech Pathology Unit for long term behavioural treatment. It is imperative that good communication exist between speech clinicians in the "home" care unit and the Orofacial Rehabilitation Unit. This communication is enhanced by providing in-service discussion with speech clinicians through the region concerning the criteria for admission to the palatal lift program, the technical characteristics of the appliance and the modification procedures utilized by the prosthodontist. In addition, it is necessary for the Orofacial Rehabilitation Unit speech pathologist to describe the methods used in the laboratory to assess the efficiency of the prosthesis to collaborating clinicians. Visits to the Unit to observe the fitting sessions, observation of the speech laboratory examinations and open discussions about the patient's particular physical and psychological problems that may limit compliance with the program are important for the provision of the best possible integrated care. Written reports also help each unit maintain performance appraisal information about the patient and the team(s) providing the care.

For post-fitting palatal lift modification, clinicians are asked to observe carefully the amount of nasal air emission present in speech during therapy sessions. Clinical assessment of nasal air emission using a cold mirror, U tube manometers with nasal olives attached, or by use of such tools as "See Scape" or more sophisticated pressure/flow equipment during a variety of speech tasks allows the clinician to note changes and to re-refer the patient for further modification of the appliance. Modification to the appliance may be made over an eight-month to two-year period, depending upon the type of insult and the results of various medical and behavioural treatment plans. Further, periodic dental rechecks of the patient's overall oral hygiene, dentition viability and prosthesis care are necessary.

The speech and prosthodontic procedure described in this paper represent one approach to evaluation and management of one of the multiple valve components of the speech system (Netsell and Daniel, 1979). Additional basic and applied research using more sophisticated techniques (Barlow and Abbs, 1983; Muller and Brown, 1980) is needed to determine the most efficacious methods of assessing the speech articulators during prosthetic management. Likewise, dental researchers must continue to develop new materials, better impression and more rapid fitting techniques to aid the rehabilitation process.

In conjunction with other speech clinicians and with basic and applied research professionals, it is hoped that a more thorough understanding of the underlying nature of the damage to various parts of the nervous system will develop. Such information should aid the rehabilitation team in making decisions about the fabrication, fitting and modification of prosthetic speech appliances in order to offer the patient the best opportunity for improved communication.

Conclusions

The speech evaluation of dysarthric patients with velopharyngeal imcompetence employing perceptual, aerodynamic and acoustic assessments of the multiple speech valves within the system is well supported by the works of Netsell and Daniel (1979), Netsell (1982), and Rosenbek (1984). By continually observing the "multilevel control mechanisms" (Abbs and Kennedy, 1982; Netsell, 1982) subserving speech motor control in neurologically damaged patients undergoing management (palatal lift) of one speech valve (velopharyngeal), professionals may measure the effects of treatment on speech output (McNeil and Kennedy, 1984).

The authors have found the present approach useful for assessing the benefits of a palatal lift prostheses for dysarthric patients with accompanying velopharyngeal incompetency. Pre- and post-fitting measures support the findings of other researchers and clinicians (Bedwinek and O'Brien, 1985; Mazaheri and Mazaheri, 1976; LaVelle and Hardy, 1979; and Aten, McDonald, Simpson and Gutierrez, 1984).

It has been our impression that factors in addition to those discussed in the body of this paper affect the benefits of palatal lift prostheses. Further data are needed to demonstrate the effects of type of insult, length of time since the insult, neurological stability, cognitive and psychological integrity, and the compliance of the patient for continued medical, dental and behavioural treatment on speech improvement following the placement of a palatal lift prosthesis.

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Erratum

In Volume 9, Number 5, 1985 of *Human Communication Canada* an article entitled *Central Process and Aging* by Moe Bergman, Ph.D., Professor of Audiology, Tel-Aviv University, Israel, was published. Unfortunately, several of the figures were mislabeled. The following corrections should be made to that article:

a) The graphics for Figures 2 and 3 are reversed. The captions associated with those graphics remain in place.
b) The appropriate graphic for Figure 4 on page 159 may be found above the title for Figure 8 on page 161.
c) The appropriate graphic for Figure 5 on page 160 may be found above the title for Figure 10 on page 162. The graphic for Figure 8 on page 161 may be found above the title for Figure 4 on page 159.
d) The last word in the title for Figure 9 on page 161 should be "varied" and not "verified".
e) The appropriate graphic for Figure 10 on page 162 may be found above the title for Figure 8 on page 161. In addition the caption for Figure 10 should read: "Figure 10: Mean increases in time required to read a passage aloud at two delayed auditory feedback times. Left — 200 ms; right — 320 ms."

The editors of the special issue of *Human Communication Canada* entitled *Central Auditory Processing and Disorders* express their regrets at these errors and apologize to Dr. Bergman and readers of this Journal.