COMPARISON OF VELOPHARYNGEAL CLOSURE AND PERCEPTUAL SPEECH CHARACTERISTICS IN INDIVIDUALS WITH SUBMUCOUS CLEFT PALATE

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Abstract

The submucous cleft palate is a congenital condition which is characterized by an abnormal attachment of soft palate muscles to the hard palate. These individuals are at risk for abnormal speech characteristics such as hypernasal resonance, nasal air emission, and articulatory errors. Other symptoms may include persistent middle ear problems and swallowing difficulties. The present study is aimed to study the velar anatomy and function using Cineradiographic procedure and its association with perceptual speech characteristics of individuals with unoperated submucous cleft palate. 10 individuals with submucous cleft palate in the age range of 7 to 18 yrs (7 males and 3 females) were considered for the study. The speech samples consisted of vowels, high pressure words and standardized oral sentences. Right lateral cineradiographic videos were obtained for all the speech samples and were rated by three speech language pathologist for velar anatomy and function. For perceptual analysis of speech, the same samples were audio recorded in a quiet room and were presented to the same judges for perceptual rating. The results showed that all the subjects considered had inadequate velopharyngeal closure (56%). There was significant strong negative correlation for degree of velopharyngeal closure with hypernasality ($r_{s=}$-0.68) and nasal air emission (r_s=-0.71). No significant correlation for speech intelligibility and voice with velopharyngeal closure. Inter judge reliability had a higher internal consistency for all the perceptual speech parameters. The results indicated that both velar function and perceptual speech characteristics provide vital information that will be helpful in diagnosis and management of individuals with submucous cleft palate

Key words: *Submucous cleft palate, Cineradiography, Velopharyngeal closure*

Introduction

Submucous cleft palate (SMCP) is a congenital deformity of the soft palate. It is a defect of the muscles attached to soft palate with an undamaged oral and nasal mucosa (Shprintzen, McCall, Skolnick, & Lencoine, 1975). It was first described by Roux (1825) and the incidence was reported to be 1 in 10,000 to 1 in 20,000 of the population (Nasser, Fedorowicz, Newton, & Nouri, 2008). The cardinal symptoms of submucous cleft palate were a transparent region in the midline of the soft palate, a bifid uvula, and a triangular notch at posterior nasal spine (Calnan, 1954). However only 10% of the individuals are symptomatic and all the signs need not to be present for diagnosis of submucous cleft palate (Weatherly–White, Sakura, Brenner, Stewart, & Ott, 1972). Some individuals with SMCP are reported to have speech problems like hypernasal speech, articulation errors, and nasal air emission due to Velopharyngeal Dysfunction (VPD (Weatherly-White, 1976).

Velopharyngeal dysfunction in SMCP occurs when there is an inadequate velopharyngeal (VP) closure caused due to structural and functional deficit of nasopharynx. The inadequate velopharyngeal closure results in escape of air through the nose during the production of oral pressure consonants which results in inappropriate nasal resonance. The assessment of speech in individuals with VPD is grouped under two major categories such as perceptual and instrumental assessment procedures. Perceptual assessment of speech is an important measure in the diagnosis of velopharyngeal dysfunction beside oral mechanism examination and case history (Trindade & Trindade Junior, 1996; Kummer, Briggs & Lee, 2003). Through perceptual evaluation of resonance in individuals with velopharyngeal dysfunction, assessment can be made for the occurrence of hypernasality, nasal air emission and compensatory articulation during speech production.

The instrumental assessment of velopharyngeal structures includes direct and indirect visualization procedures. The indirect procedures include nasoendoscopy and cineradiography / cinefluroscopy (Golding–Krushner, Argamaso, & Cotton, et al.1990). Cineradiography is a non-invasive radiologic procedure envisioned to evaluate the ability of velopharyngeal closure. Video recording produces a continuous record of the velopharyngeal mechanism during speech. Cineradiography provides the most accurate measures of velar structure and function. The

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measures related to velum that are utilized are pharyngeal depth, velar length, size of the opening, degree of contact during closure. A colloidal barium sulphate, radiopaque material is injected in to the nares to provide contrast in the cinefluoroscopic image. Different angles such as lateral, frontal and basal views can be used in isolation or in combination. The technique is used to evaluate various types of velopharyngeal insufficiency, including cleft palate. Cinefluroscopy is often performed in addition to surgical preparation in individuals who do not respond to traditional treatment such as speech therapy.

The perceptual, structural, physiological characteristics of the velopharyngeal mechanism and speech characteristics were previously studied by many authors (Calnan, 1954; Dalston & Warren, 1985; Dalston & Seaver, 1990; Witt & D'Antonio, 1993; Baken & Orlikoff, 2000) and they have noted that the relationship between the perceived degree of hypernasal resonance and size of the velopharyngeal gap is nonlinear. The degree of nasality reflects the multifaceted interaction of a number of factors, including articulation; variations in oral, pharyngeal, and nasal cavity size; vocal pitch and intensity; respiratory effort; and the ratio of oral and nasal acoustic impedances (Baken & Orlikoff, 2000). Additional variables that may affect the perception of nasality include articulatory timing (Baken & Orlikoff, 2000); the extent of time the valve is open (Dalston & Seaver, 1990; Warren, Dalston, & Mayo, 1993), and the speaker's articulatory compensations for the velopharyngeal opening (Watterson & Emanuel, 1981; Folkins, 1985).

Kummer, Curtis, Wiggs, Lee, and Strife (1992) conducted a study to investigate a relationship between velopharyngeal gap size and perceptual speech characteristics of individuals with Velopharyngeal dysfunction. The subjects included eight individuals with hypernasality only, 10 individuals with hypernasality and audible nasal emission devoid of any nasal rustle, and 10 individuals with nasal rustle only. The videofluoroscopic images were analyzed using nine parameters and was correlated with perceptual parameters. The results of the rating showed that velopharyngeal contact and lateral pharyngeal wall movement were significantly different between the two hypernasality groups and the nasal rustle group. These two variables were sensed to be related to velopharyngeal gap size. Based on the differences, it was concluded that individuals signifying hypernasality, with or without audible nasal emission or nasal rustle, had significantly larger velopharyngeal gaps than those with nasal rustle only. This finding suggested that velopharyngeal gap size may be predicted based on perceptual assessment.

Kummer et al. (2003) further studied the relationship of velopharyngeal gap size and characteristics of speech in individuals with velopharyngeal dysfunction secondary to cleft lip and palate. They studied 173 children retrospectively in the age range of 3 to 12yrs. Based on the perceptual rating scale the subjects were further divided into subsections such as subjects with nasal rustle only (21), hypernasality without nasal air emission (27), hypernasality with nasal air emission (89), hypernasality with nasal rustle (27). The velopharyngeal closure was assessed by using videofluroscopy and nasoendoscopy. The videos were rated by using rating scale for videofluroscopic speech studies (Kummer & Neale, 1989). The results exhibited that moderate and severe hypernasality contributed considerably to the prediction of a large velopharyngeal gap size. The nasal rustle contributed significantly to prediction of a small gap size. Perceptual features of speech accurately predicted velopharyngeal gap size for 121 of the 173 individuals (70%). They concluded that if a subject had a moderate or severe hypernasality it helps in predicting greater velopharyngeal gap and the nasal rustle predicts lesser gap.

Dudas, Deleyiannis, Ford, Jiang, and Losee (2006) studied the effectiveness of perceptual speech characteristics in predicting velopharyngeal closure. Twenty four children with VPD were included in a retrospective study where all the individuals underwent primary palatoplasty. All the subjects were evaluated for perceptual speech characteristics using the Pittsburgh Weighted Speech Scale (PWSS) and for velopharyngeal structure and function using lateral videofluoroscopy. The results showed that on lateral view the velopharyngeal closure correlated moderately with total scores of PWSS and the phonation scores of PWSS. They concluded that although perceptual speech characteristic provides some clues on prediction of velopharyngeal closure, the videofluroscopy itself provides some valuable prediction of VPD.

The above studies mostly deal with the study of perceptual speech characteristics such as hypernasality, phonation and nasal air emission's prediction on velopharyngeal anatomy and function. The subjects they considered were individuals with velopharyngeal dysfunction secondary to repaired cleft palate and further they grouped these subjects based on their speech characteristics. The present study is aimed to investigate the association between velar function and speech characteristics of individuals with submucous cleft palate only. SMCP is a structural

defect of the soft palate, mainly the musculus uvulae and levator veli palatini which attaches onto the palatine bone instead of creating an adequate muscular sling and palatine aponeurosis. The muscle alignment in individuals with SMCP is completely different from that of other types of cleft palate. Hence there is a need to explore the velar function and speech characteristics in individuals with SMCP.

Aim of the study

To study the relationship between velar structure and function based on cineradiographic videos with the perceptual speech characteristics of individuals with submucous cleft palate.

Objectives

1) To study the velar function and structure using cineradiography in individuals with submucous cleft palate.
2) To study the association between velopharyngeal closure and perceptual speech characteristics such as hypernasality, nasal air emission, voice and speech intelligibility in individuals with submucous cleft palate.

Method

Participants: Ten individuals with unoperated submucous cleft palate (SMCP) in the age range of 7 to 18 yrs (7 Males and 3 Females) were considered for the present study. The native language of all the subjects was Kannada, a Dravidian language. All the participants were evaluated by Craniofacial Team which included a plastic surgeon, speech language pathologist, psychologist and an orthodontist at Unit for Structural Orofacial Anomalies (U-SOFA), All India Institute of Speech and Hearing (AIISH). All the individuals considered for the study were diagnosed to have velopharyngeal dysfunction and did not have all the traid symptoms of submucous cleft palate. Informal language assessment revealed normal language ability in all the subjects. Individuals with congenital heart defects, syndromic features, hearing impairment and cognitive impairments were excluded from the study. The demographic details of the subjects are shown in Table 1.

Instrumentation: The instrument used for Cineradiographic/Cinefluroscopic evaluation of participants was Siemens Axiom Artis U X-ray system, at Cath lab, Vikram Hospital. All investigations were made with the help of a remote-operated digital C-arm device with an image intensifier of 16-inches and focal spot range of 0.6 to 1.2 mm was considered for the present study.

Table 1: Demographic details of the subjects

Subjects	Age (yrs)	Gender	Diagnosis
A	9	M	SMCP
B	7	M	SMCP
C	14	M	SMCP
D	18	F	SMCP
E	7	M	SMCP
F	9	M	SMCP
G	18	M	SMCP
H	11	F	SMCP
I	17	F	SMCP
J	13	M	SMCP
Average	12.3 yrs	*SMCP – Cleft Palate	Submucous

Cineradiographic images were obtained for the speech study with 30 images per second and were recorded using high-resolution CCD camera warranting an excellent image quality. A DDO function (Digital Density Optimization) spontaneously compensates for various densities. The program integrated for image post-processing optimizes as well as supports diagnosis and additional treatment steps.

Procedure

The speech samples consisted of isolated vowels (/a/, /i/, /u/), ten words loaded with high pressure consonants, standardized five oral sentences (Jayakumar & Pushpavathi, 2005). For cineradiographic evaluation, the subject was taken to cath lab and instructed to sit in upright and supine position in a seat placed at centre of the C-arm that is between fluoroscope and image intensifier of Siemens Axiom Artis X-ray system. Before starting this procedure a suspension of colloidal barium sulphate, a radiopaque substance is instilled in the nasopharynx for better visualization of the contrast. The subjects were asked to read the stimulus which was on a white sheet and the procedure was done with a help of radiologist. The obtained x-ray image was amplified by the electronic intensification, making it bright enough to be recorded in the video camera. The radiation exposure for each subject was approximately 2 roentgens. The obtained images were blinded and evaluated by three speech language pathologist (SLP) experienced in the field of craniofacial anomalies by using rating scale for videofluroscopic speech studies (Kummer et al., 1989).

Analysis

Cineradiographic video: The rating scale for videofluroscopic speech (Kummer et al., 1989) evaluates the structural and functional aspects of velopharyngeal mechanism. The rating scale

includes subdivisions for velopharyngeal closure, velar length,velar thickness, height of the velum, tongue motion, passavant's ridge and adenoids. The speech language pathologists were considered as judges. They were blindfolded about the details of the cineradiographic videos and they were asked to rate the video samples based on above mentioned parameters. They were informed to view the videos as many times before rating them.

Perceptual speech samples: For perceptual evaluation speech characteristics such as hypernasality, nasal air emission, voice and speech intelligibility were considered. The stimulus consisted of same high pressure words and sentences spoken by the subjects during cineradiographic evaluation which was recorded through digital audio recorder (Olympus digital recorder, 550M). The audio samples were blindfolded and judged by the same three speech language pathologists after a period of one week after rating the cineradiographic videos. The Henningsson, Kuehn, Sell, Sweeney, Trost-Cardamone, and Whitehill (2008) speech assessment rating scale (0-4) was used for rating the perceptual speech characteristics such as hypernasality, nasal air emission, voice and speech intelligibility.

Ethical consideration: This study was conducted with the written consent of the participants or their parents. Participants were provided with the information in the language he/she is capable of understanding and were explained about the aim, objectives, method of the research and approximate duration of testing.

Statistical Analysis: The mean scores for velar anatomy function and speech characteristics obtained from speech language pathologists were entered in Statistical Package for the Social Sciences software (IBM SPSS version 20) for statistical analysis. To find the association between velopharyngeal closure and perceptual speech characteristics Spearman's rank correlation co-efficient (r_s) was calculated. Interjudge reliability was calculated to find the internal consistency between the judges on procedures used.

Results

The results of this study was explained in the following sections

a) *Mean percentage scores of the rating for velar function and perceptual speech in SMCP.*

The judges rated cineradiographic videos of different speech samples. The following Figure 1 depicts the few images of the velopharyngeal closure during production of vowels (/a/, /i/) and pressure consonants (/p/, /s/) in individuals with submucous cleft palate.

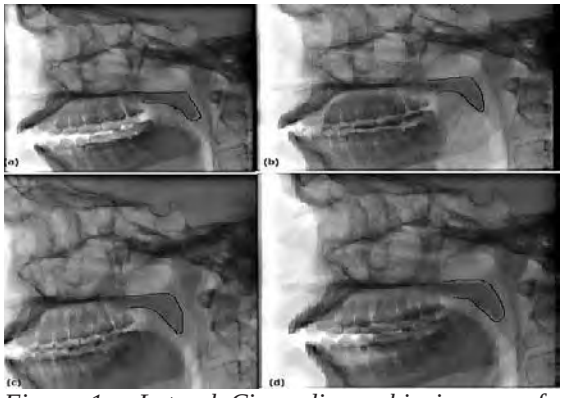
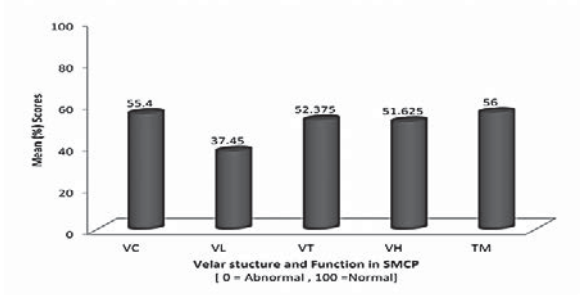


Figure 1: Lateral Cineradiographic images of speech production in an individual with submucous cleft palate (a) vowel /a/ (b) vowel /i/ (c) pressure consonant /p/-in /pʌtʌ/ (d) pressure consonant /s/ -in /sadʒa/

The mean percentage scores of ratings done for cineradiographic videos by three speech pathologists are displayed in the below Figure 2.



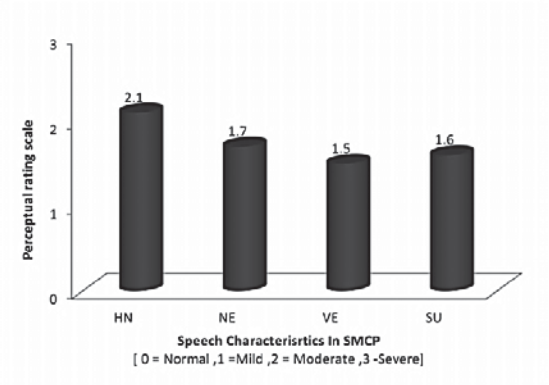
[VC =Velopharyngeal Closure, VL =Velar Length, VT =Velar thickness, VH =Velar height, TM =Tongue Motion]

Figure 2: Mean perceptual rating of lateral cineradiographic speech samples in Individuals with SMCP

The subdivisions included velopharyngeal closure (55.4%), velar length (37.5%), velar thickness (52.37%), velar height (51.62%) and tongue motion towards normal (56%). Among the subdivisions the velar length was rated as shortest with a lower percentage and tongue movement got the highest rating percentage. And none of the subjects considered for the study got 100% normal velopharyngeal closure as everyone was diagnosed with velopharyngeal dysfunction.

The mean ratings for perceptual speech characteristics such as hypernasality, nasal emission, voice and speech intelligibility of individuals with submucous cleft palate are represented in Figure 3. The rating scale used was

a 4-point rating scale [0=Normal, 1 = Mild, 2=Moderate and 3= severe] given by Henningsson et al. (2008).



[HN-Hypernasality, NE-Nasal Emission, VE-Voice, SU –Speech Intelligibility]

Figure 3: Mean perceptual rating of speech characteristics in Individuals with SMCP

The subdivisions include hypernasality (2.1), audible nasal emission (1.7), voice (1.5) and speech intelligibility (1.6). Among the subsections hypernasality was reported to have moderate degree followed by nasal air emission and speech intelligibility. The least rating was mild degree for perceptual voice evaluation. And none of the subjects had normal resonance and nasal air emission was not present.

b) Relationship between velopharyngeal closure and perceptual speech In SMCP

To find the association between velopharyngeal closure and perceptual speech characteristics Spearman's rank correlation co-efficient (r_s) was calculated for velopharyngeal closure and each subdivision of perceptual characteristics such as hypernasality, audible nasal air emission, voice and speech intelligibility. The Spearman's correlation co-efficient for each subdivision was tabulated in the Table 2.

Table 2: Relationship between velopharyngeal closure and perceptual speech

Speech	Nasality	Nasal Emission	Voice	Speech Intelligibility
Correlation co-efficient (r_s)	-0.687*	-0.71*	-0.289	-0.285
P Value	0.028	0.021	0.48	0.424

*Correlation is significant at 0.05 levels

The results showed there was significant negative relationship between degree of velopharyngeal closure and hypernasality ($p = 0.02 < 0.05$).The association between velopharyngeal closure and hypernasality was strong moderate correlation (r_s =0.68) it was represented in the Figure 4.

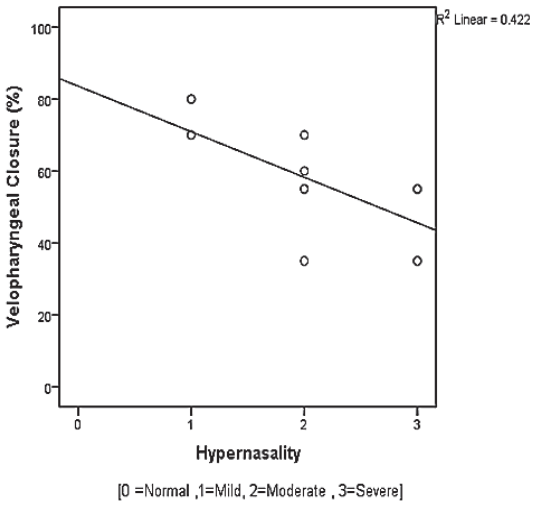


Figure 4: Relationship between VP closure and hypernasality

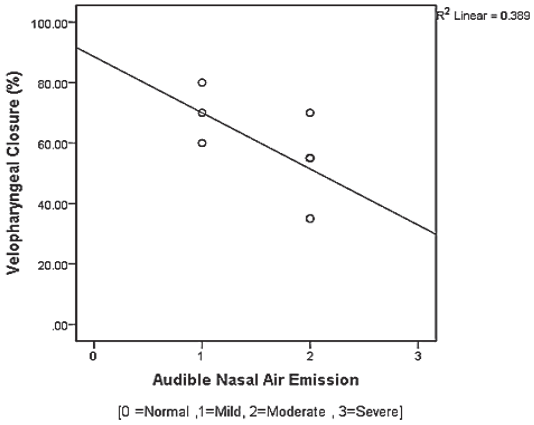


Figure 5: Relationship between VP closure and Audible Nasal air emission

As the velopharyngeal closure decreased there was an increase in the degree of hypernasality. The results also showed significant negative relationship between velopharyngeal closure and audible nasal air emission and the correlation was strong (r_s =0.71).

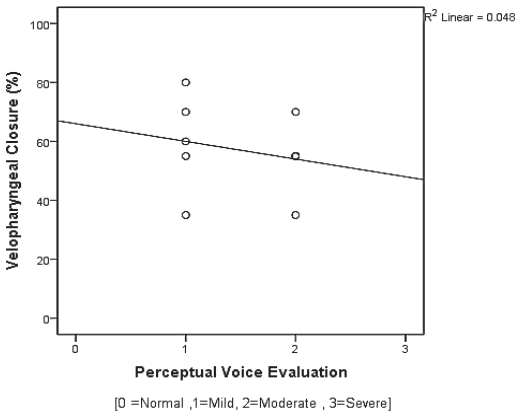


Figure 6: Relationship between VP closure and voice

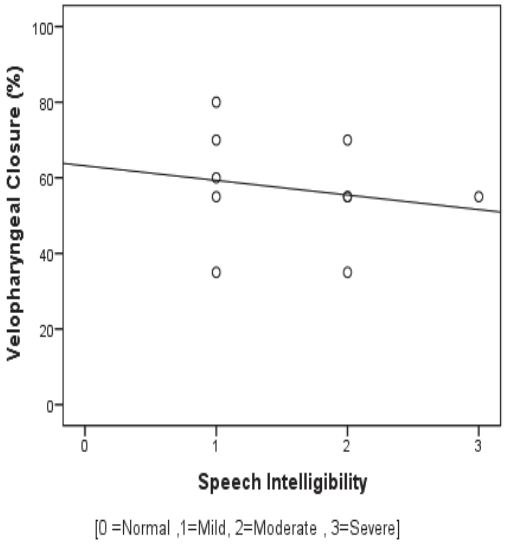


Figure 7: Relationship between VP closure and speech intelligibility

The significant negative relationship between nasal air emission and velopharyngeal closure at 0.05 levels was observed in Figure 5. When the degree of velopharyngeal closure increased there was a reduction in the degree of audible nasal air emission. But there was no significant difference for other two subsections such as voice ($p = 0.48 > 0.05$) and speech intelligibility ($p = 0.42 > 0.05$) in relation with degree of velopharyngeal closure. There was a weak negative correlation for the both subsections which was depicted in the above figures 6 and 7.

c) Inter judge reliability between the judges for perceptual rating scales

Inter judge reliability was calculated between the four judges for rating of velopharyngeal closure and perceptual speech characteristics. Cronbach's alpha (α), co-efficient of reliability was calculated for each subsections and represented in the Table 3.

Table 3: Interjudge reliability between the judges for VP closure and perceptual speech

	VP Closure	Hyper-nasality	Nasal Emission	Voice	Speech Intelligibility
Cron-bach's alpha (α)	0.860*	0.90**	0.82*	0.83*	0.928**

**Excellent Internal consistency *Good Internal consistency

The results showed that there was higher internal consistency between the three judges for hypernasality and speech intelligibility. There was good inter judge reliability between the ratings of the judges for nasal air emission, voice and velopharyngeal closure.

Discussion

The present study aimed to study the velar structure and function using cineradiography in submucous cleft palate. It also further intended to study its relationship between perceptual speech characteristics such as hypernasality, nasal air emission, voice and speech intelligibility in individuals with submucous cleft palate (SMCP). The results showed that among the speech subsections that were perceptually evaluated the hypernasality and audible nasal air emission were the significant predictors of degree of velopharyngeal closure. And the reliability between the perceptual ratings of the judges had a higher internal consistency for both the perceptual rating scales.

The cineradiographic evaluation, an indirect visualization procedure was used in this study to evaluate the velar structure and function in individuals with submucous cleft palate. The assessment was done in relation to parameters like velopharyngeal closure, velar thickness, velar length, velar height and tongue motion. All the subjects in the present study were found to have reduced velopharyngeal closure because of the velopharyngeal dysfunction (VPD). This may be due to short soft palate which can be related with the previous literature that VPD in submucous cleft palate (Kaplan, 1975). The short soft palate resulted in the reduced velar length which was rated lower than other subsections. The poor velar elevation in SMCP is due to abnormal insertion of the soft palate muscles into the hard palate. This poor muscle orientation leads to VPD (Sommerald, Fenn, Harland, Sell , Birch , Dave et al., 2004).

The relationship between degree of velopharyngeal closure and hypernasality showed a significant inverse association. The degree of velopharyngeal closure reduced as there was an increase in the hypernasality and this relation was nonlinear. The results of this study were highly in support by the previous studies (Dalston & Seaver, 1990; Witt & D'Antonio, 1993; Baken & Orlikoff, 2000; Kummer et al., 2003; Dudas et al., 2006).This may be relatively due to the relation between impedances of oral and nasal cavity which affects the perception of hypernasality. This association changes with effort, articulatory pattern, the size of the vocal tract, and timing of velopharyngeal closure in connected speech. (Zimmerman, Karnell, & Rettaliata, 1984; Stevens, 1998; Baken & Orlikoff, 2000; Kummer et al., 2003).

Then association between the velopharyngeal closure and audible nasal air emission was

significantly strong and non-linear. As velopharyngeal closure decreases the nasal air emission increases leading to hypernasality (Shprintzen & Golding-Kushner, 1989). This may be again related to the reduced velar length and inadequate oral and nasal coupling. Therefore nasal air emission is considered to be one of the major predictor of velopharyngeal closure in persons with velopharyngeal dysfunction. In contrast there was a weak or poor correlation between perceptual voice and speech intelligibility. But there was negative relationship between voice impairment and degree of VP closure. This may be due to the fact that velopharyngeal gap during speech requires the subjects to place grater phonatory effort for increasing their loudness. The factors that contribute to the weak correlation were as most of the subjects considered were children they are more prone to have enlarged adenoids and vocal nodules.

The weak correlation between speech intelligibility and velopharyngeal closure may be attributed to the type of speech sample used for perceptual rating of this subsection of the rating scale. These results of this subdivision are contradictory to the results obtained for other speech characteristics. The function of velopharyngeal mechanism in connected speech is very complex because of the length of the sample (Kummer et al., 2003). The relationship between velopharyngeal closure and speech intelligibility was nonlinear and difficult to predict its association. In connected speech, the perceptual speech characteristics provided some information in addition to visualization procedures such as videofluoroscopy and nasoendoscopy.

In the present study the results showed that hypernasality and audible nasal air emission were strong predictors of velopharyngeal closure. Although their association was high, there are other factors which influence the velopharyngeal closure. And influence of these factors was more when it is in connected speech. The variables other than VP closure which was discussed previously may influence the perceived quality of resonance and nasal air emission. So along with the examination of velopharyngeal anatomy and function using videofluoroscopy some perceptual cues from the perceptual assessment of speech characteristics would give additional information on the perceived speech quality.

Conclusions

The present study aimed studying the velar anatomy and function using cineradiography and its relationship with perceptual rating of speech characteristics (Henningsson et al., 2008). All the participants had velopharyngeal dysfunction and reduced velar length. The association between perceived speech parameters such hypernasality and nasal air emission had strong correlation with velopharyngeal closure. There was a weak correlation between velopharyngeal closure, voice and speech intelligibility. Thus evaluations of speech and velopharyngeal structure are important components in identification of an individual with VPD. The present study studied the predictors of velopharyngeal closure which further helps in the assessment and management of velopharyngeal dysfunction. The sample size considered for this study is very small and it cannot be generalized for the whole group of individuals with submucous cleft palate. So future research should focus on a larger sample size involving individuals with SMCP. In the present study for rating velar anatomy only right lateral videofluroscopic images were used. For studying the velopharyngeal sphincter mechanism all the three views such as frontal, basal and lateral view images should be considered for rating.

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