EFFECT OF SURGERY ON SPEECH CHARACTERISTICS IN INDIVIDUALS WITH VELOPHARYNGEAL DYSFUNCTION: PRE – POST OPERATIVE COMPARISON

Thesis submitted to the University of Mysore for the degree of

DOCTOR OF PHILOSOPHY (Ph.D)

IN

SPEECH LANGUAGE PATHOLOGY

By

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CERTIFICATE

This is to certify that the thesis entitled **"Effect of Surgery on Speech Characteristics in Individuals with Velopharyngeal Dysfunction : Pre-Post Operative Comparison"** submitted by Mr. Gnanavel.K for the degree of Doctor of Philosophy (Speech-Language Pathology) to the University of Mysore was carried out at the All India Institute of Speech and Hearing, Mysuru.

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DECLARATION

I declare that this thesis entitled **"Effect of Surgery on Speech Characteristics in Individuals with Velopharyngeal Dysfunction : Pre-Post Operative Comparison"** which is submitted for the award of the degree of Doctor of Philosophy (Speech-Language Pathology) to the University of Mysore, is the result of original work carried out by me at the All India Institute of Speech and Hearing, Mysore, under the supervision of Dr. Pushpavathi.M, Professor of Speech Pathology, All India Institute of Speech and Hearing, Mysuru. I further declare that the results of this work have not been previously submitted for any degree.

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DECLARATION

I declare that this thesis entitled "**Effect of Surgery on Speech Characteristics in Individuals with Velopharyngeal Dysfunction: Pre-Post Operative Comparison"** which is submitted for the award of the degree of Doctor of Philosophy (Speech Language Pathology) to the University of Mysore, has been revised on the basis of the evaluation report extract provided and the revised thesis is fit for re-submission.

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Abstract

Velopharyngeal dysfunction (VPD) is one of the common conditions secondary to cleft lip and palate. The speech characteristics in VPD include hypernasality, nasal air emission, compensatory articulation errors and unintelligible speech. The perceptual and instrumental assessment of speech characteristics are considered to be effective in evaluating the speech outcome following surgical intervention. The present study investigated the effect of surgery on speech characteristics of individuals with VPD. A total of 30 Kannada speaking individuals with VPD secondary to repaired cleft palate in the age range of 7 to 25 years (mean age =14.2 years) participated in the study. They were classified into three groups (group I- palatoplasty, group II – pharyngoplasty and group III- combined surgery) based on the type of secondary surgical management considered for VPD. The participant's speech samples considered for analysis were spontaneous speech, repetition of high pressure words, isolated vowels (/a/, /i/, /u/), voiced and unvoiced CV syllables standardized oral and nasal sentences in Kannada language which were audio-video recorded across three conditions (condition I- prior to surgical intervention, condition II- 3 months and condition III- 6 months after surgical management with 15 sessions of speech therapy). The speech characteristics such as articulation, resonance, speech intelligiblity and voice in individuals with VPD were measured using perceptual and instrumental methods across conditions and groups. The results showed significant reduction in the articulation errors, nasalance values, hypernasality, nasal air emission, improvement in the speech understandability and voice characteristics from condition I (pre-operative) to condition II and III (post-operative).The compensatory articulations errors and resonance problems such as hypernasality reduced after 15 session of speech therapy. The hyponasality was not observed post operatively in subjects considered for the study. Among the conditions significant differences were seen on the speech parameters between condition I (pre surgery) and condition III (6 months followup). The cineradiographic evaluation of velopharyngeal closure reduced from severe in pre-operative to moderate degree in the post-operative condition. The nasalance values for voiced consonants were found to be higher than unvoiced consonants across vowel context (/a/, /i/and/u/). Across groups, statistical analysis showed no significant difference between the groups (surgery type) and on mean

scores Furlows double opposing Z plasty group showed better outcome followed by pharyngoplasty and combined surgery group. The association between perceptual judgement of hypernasality and nasalance values of sentences indicated moderate relationship for post-operative conditions. The relationship between nasalance values of vowels with velopharyngeal closure rating showed strong association preoperatively and moderate correlation post operatively. The present study profiled the perceptual and instrumental assessment of speech characteristics of individuals with velopharyngeal dysfunction. The speech outcome following secondary intervention was effective in individuals with VPD. The assessment protocol considered for the present study involving perceptual and instrumental assessment procedures may be useful in measuring the speech outcome in individuals with VPD.

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CHAPTER I

INTRODUCTION

Cleft lip and/or palate are common congenital birth defects occurring due to inadequate closure of the lip and/or the palate during early fetal growth during pregnancy. Cleft lip and palate (CLP) affects approximately 1 in 600 live births in the world (Correa & Edmonds, 2002; Mossey & Little, 2002). The prevalence of CLP in India is estimated as 9.1 per 10,000 depending upon various epidemiological factors such as ethnicity, geography location and socio – demographic parameters (Banerji & Dhakar, 2013).

Individuals with CLP form a heterogeneous group varying from individuals who have an isolated cleft to those in whom CLP is more of a feature of a syndrome. This heterogeneous nature makes it hard to generalize about the characteristic features of communication disorders in CLP. D'Antonio and Scherer (2008) listed numerous factors such as type and severity of cleft, age and time of surgery , effectiveness of repair, presence of fistula, unoperated residual cleft, status of velopharyngeal function, hearing status, socioeconomic and linguistic status that could have an effect on the communication in individuals with VPD.

Individuals with CLP often demonstrate multiple associated problems which are grouped under communicative and non-communicative problems. The non-communicative problems are early feeding problems, nutritional concerns, developmental disabilities, dento-facial anomalies, orthodontic deformities, hearing problems, and psychosocial impairments. The communicative or speech related problems in individuals with CLP include hypernasality, hyponasality, nasal air emission, compensatory articulations, weak pressure consonants and unintelligible speech. Nasality is the common symptom that occurs due to velopharyngeal dysfunction in individuals with CLP.

Velopharyngeal dysfunction (VPD) occurs when there is an inadequate velopharyngeal closure caused due to structural and functional deficits of nasopharynx. The inadequate velopharyngeal closure results in air escape through the nostrils during the production of high pressure oral consonants which results in inappropriate nasal resonance. VPD is a comprehensive term that was widely acknowledged by several authors (D'Antonio, Muntz, Province, & Marsh, 1988; Jones, 1991; Marsh, 1991; Morris, 1992; Penfold, 1997; Witt et.al, 1997). The term VPD is most commonly used because it avoids any confusion regarding the cause of the problem and it generally means any disorder of the velopharyngeal closure and it includes variety of causes such as velopharyngeal insufficiency, incompetency and mislearning.

The velopharyngeal insufficiency is a structural defect in which the soft palate is too short to touch the posterior pharyngeal wall. During the velopharyngeal closure the short velum is unable to make contact with the posterior pharyngeal wall leading to incomplete velopharyngeal closure. There are various causes for the reduced length of the velum. The velopharyngeal insufficiency is more frequently noticed in persons with a history of cleft palate. In spite of surgical management of the palate, approximately 20% of these individuals will have VPD due to inadequate length of the velum after surgical repair of the cleft of the palate. Velopharyngeal insufficiency is most commonly seen in individuals with submucous cleft palate and rarely noticed in individuals who underwent adenoidectomy. In young children, the prominent adenoid pad results in the velum adenoid closure rather than velopharyngeal closures. After adenoidectomy, the distance between the velum and posterior pharyngeal wall is greater due to the deeper nasopharynx as a result of the surgical procedure which results in incomplete velopharyngeal closure.

Velopharyngeal incompetence is a physiological deficit which results in the poor functioning of the velopharyngeal structures. The main cause of the velopharyngeal incompetence is the abnormal insertion of the levator veli palatini. When there is an abnormal insertion of this muscle, the velum will not raise during the speech to get a complete velopharyngeal closure. The lateral pharyngeal wall movement also become restricted and leads to limited medial movement which results in incomplete velopharyngeal closure. When the defects are seen in the cranial nerves such as glossopharyngeal nerve (IX), the vagus nerve (X) and the hypoglossal nerve (XII) it can cause velopharyngeal paralysis or the paresis of the soft palate and the muscles of pharynx (Rousseaux, Lesoin, & Quint, 1987). Mostly the velopharyngeal paralysis caused by these cranial nerve defects are unilateral and usually occur in the absence of any other oro motor defects. In unilateral paralysis, the velum will elevate normally on the unaffected side while on the affected side the velum will drop down which results in the incomplete closure of the velum.

The velopharyngeal mislearning is the inappropriate functioning of the velopharyngeal mechanism due to the faulty learning of the different articulation patterns. This can occur due to change in place of articulation from the oral to the pharyngeal or nasal production of oral sounds. This atypical production can lead to phoneme-specific nasal emission usually during the production of sibilant sounds. This is not a primary velopharyngeal disorder that is caused due to velopharyngeal insufficiency or velopharyngeal incompetence. The velopharyngeal mislearning also causes the abnormalities in the resonance and the nasal air emission which are similar to the characteristic caused by the primary velopharyngeal disorder.

The speech characteristics of individuals with VPD are divided into active and passive characteristics. The passive characteristics are produced due to the structural abnormalities or dysfunction which includes audible nasal air emission accompanying obstruent consonants, weak obstruent consonant production, substitution of nasal consonants for oral sounds, hypernasal resonance distortion. Hypernasality is the perceptually aberrant hallmark feature that is obvious in the speech characteristics of all individuals with VPD irrespective of the cause such as velopharyngeal insufficiency, velopharyngeal incompetence and faulty behaviours.The speech characteristics that suggest learned and compensatory behavior such as maladaptive posterior placement and voice deviations due to laryngeal hyper function in VPD are considered as active speech characteristics.

The assessment of speech characteristics is an important task of the speech–language pathologist (SLP) working for the rehabilitation of individuals with VPD. The assessment is grouped under two major categories such as perceptual and instrumental assessment procedures. Perceptual assessment of speech is an essential part in the diagnosis of VPD, along with physical examination and clinical history. The main purpose of the perceptual speech assessment is to determine the speech characteristics and cause of the speech problem to plan for suitable treatment and recommendations. Perceptual speech evaluation particularly resonance, is the cardinal method of assessing in individuals with CLP (Folkins & Moon, 1990; Sell & Grunwell, 2001). Through perceptual evaluation of resonance, assessment can be made for the presence or absence of hypernasality, nasal air emission, compensatory articulation and intelligiblity during speech. It is also possible to rate the velopharyngeal function perceptually for velopharyngeal closure, velar length, velar thickness, height of the velum based on the imaging studies.

The methods of perceptual assessment in individuals with CLP include the use of rating scales to measure the speech characteristics (such as hypernasality, audible nasal air emission and intelligibility), transcribing the speech samples phonetically and use of qualitative descriptions. The test materials include single words, sentences and spontaneous speech samples (Kuehn & Moller, 2000; Sell, 2005). There are many standardized perceptual assessment tools mentioned in the literature (American Cleft Palate-Craniofacial Association, 1993; Sell, Harding, & Grunwell, 1999; Lohmander & Olsson, 2004; John, Sell, Sweeney, Harding-Bell, & Williams, 2006; Rudnick & Sie, 2008). The studies in the literature had included perceptual assessment alone for measuring the speech outcomes following velopharyngeal surgery (Tonz, Schmid, Graf, Heeb, Weissen, et al., 2002; Cable, Canaday, Karnell, Karnell, & Malick, 2004; Abyholm, Antonio, Davidson, Kjoll, Saeed et al., 2005). However, there are few limitations of the perceptual assessment methods (Kent, 1996). The variables that have been described to manipulate the perception of nasality are: articulatory ability, audible nasal air emission, pitch and loudness (Fletcher, 1973; McWilliams, Morris, & Shelton., 1990; Zraick et al., 2000). The limitations in perceptual assessment have led to exploration for instrumental methods that can give consistent measures.

The instrumental assessment procedures are used in addition to perceptual evaluation of speech characteristics and function of velopharyngeal structures. The instrumental evaluation of speech includes indirect or acoustic based assessment and direct visualization or imaging based assessment techniques. Nasometry is an indirect computer-based procedure that provides information regarding the acoustic analysis of velopharyngeal function. It measures the ratio acoustic energy released from the nasal cavity to the total acoustic energy released from both the mouth and nares during speech production. The direct visualization procedures include nasoendoscopy and cineradiography. The nasoendoscopy is a type of endoscopy used to observe the velopharyngeal port during speech. The instrument consists of a supple fiberoptic endoscope with specialized audio/video recording equipment. The endoscope's flexible insertion tube is carefully inserted through the nasal cavity till back of the pharynx to visualize the velopharyngeal port and to record the movement of the structures during speech production. Cineradiography is a radiological procedure that is used for speech assessment in individuals with VPD. This procedure involves imaging of the velopharyngeal closure during speech production using multiple views such as lateral, anterior-posterior, base, and the Townes views. The combined uses of perceptual and instrumental methods are necessary for assessing the speech characteristics and planning surgical management of individuals with VPD.

VPD is one of the most common conditions caused secondary to cleft palate. Although the frequency of VPD following cleft palate repair may differ with age of surgery, type of surgery, severity of the cleft, and surgical skill, 10 to 25% of individuals with cleft palate will eventually require secondary surgical correction. The management of VPD is divided under two groups, prosthetic and surgical management followed by speech therapy. The surgical management of VPD include augmentation pharyngoplasty, Furlow palatoplasty as a secondary procedure, sphincter pharyngoplasty (SP), and posterior pharyngeal flap (PPF). Better speech outcome is considered as the success of the secondary surgery in individuals with VPD.

The prosthetic management is suggested for individuals with neuromuscular deficit or in individuals who have contraindication for surgery. The prosthetic management can be used as a temporary method until surgery. The type of prosthesis differs on the severity and type of the cleft. The soft palate obturator is a prosthetic device mainly used for individuals with severe velopharyngeal insufficiency which helps in improving the closure. For severe velopharyngeal incompetence, palatal lift prosthesis assists in the palatal elevation. The palatal lift is designed to raise the incompetent soft palate to the palatal plane level to allow the lateral and posterior pharyngeal walls to assist in closure. The other non-surgical management of VPD is the speech therapy in which use of behavioural exercises to reduce hypernasality.

Speech therapy for individuals with VPD are planned when the hypernasal resonance and associated speech problems are mild in degree and the surgical or prosthetic management techniques are considered too intense at the beginning of the management procedures. The speech management is also considered as an alternative management when the surgical or prosthetic management have failed to achieve complete resolution of the problem, irrespective of the cause or severity of the VPD. Thus the main aim of the speech therapy in severe degree of VPD when surgery fails is to improve residual speech defects. It is also essential to note that these individuals with severe symptoms of VPD show poor prognosis following speech therapy.

There are several speech outcome studies done on combined perceptual and instrumental assessment of individuals with velopharyngeal dysfunction after secondary surgery (Karling, Henningsson, Larson & Isberg, 1999; Tonz, Schmid, Graf, Heeb, Weissen & Kaiser , 2002 ; Dailey, Karnell, Karnell & Candy, 2006 ; Elbarbary& Ghandour , 2008 ; Van Lierde , Bonte , Baudonck , Cauwenberge & De Leenheer, 2008; Wojcicki & wojcjcka , 2010). The association between different instrumental and perceptual assessment methods were carried out to evaluate the speech in VPD. Comparisons between perceptual rating scales and nasalance scores have been studied and some of those literature had good relationship (Dalston, Warren, & Dalston, 1991; Watterson, Hinton, & McFarlane, 1996; Hirschberg et al., 2006; Sweeney & Sell, 2008) and others found to have moderate (Dalston , Neiman, & Gonzalez-Landa, 1993; Watterson, McFarlane, & Wright, 1993; Keuning, Wieneke, van Wijngaarden, & Dejonckere, 2002) even low association (Nellis, Neiman, & Lehman, 1992; Lewis, Watterson, & Houghton, 2003). A relationship between perceptual speech characteristics and velopharyngeal competence using cineradiography/ multiview videofluroscopy has been studied in the literature (Kummer, Curtis, Wiggs, Lee, & Strife, 1992; Witt, & D'Antonio, 1993; Warren, Dalston, & Mayo, 1994; Kummer, Briggs, & Lee, 2003; Dudas, Deleyiannis, Ford, Jiang & Losee, 2006).

However, the above studies did not use more systematic or universally used rating scales and assessment protocols for calculating the speech outcomes in individuals with VPD. As the incidence of VPD is high it calls for the attention of speech language pathologists (SLPs) studying the assessment and outcome of rehabilitation methods. A detailed correlation of perceptual and instrumental assessment before and after surgical repair of VPD needs to be studied in Indian context. Hence there is need to develop a detailed assessment protocol with incorporating all the speech parameters in Indian language which differ significantly from that of other western languages.

CHAPTER II

REVIEW OF LITERATURE

The Velopharyngeal dysfunction (VPD) is a universal term which defines a group of conditions resulting in air escape into the nasal cavity during production of high pressure oral consonants. The speech of individuals with VPD is characterized with hypernasality, nasal emissions, and poor speech intelligibility. VPD can occur as a consequence to several causes such as anatomic, neural, or behavioural anomalies. To categorize the cause of VPD, subjects must undergo a comprehensive evaluation of velopharyngeal mechanism, through perceptual speech evaluation and instrumental evaluations, including video nasoendoscopy and multiview videofluoroscopy is pivotal in categorizing the cause for VPD. An optimal management of individuals with CLP can be possible only when the multidisciplinary team of professionals assess and discuss the results of perceptual and instrumental procedures. A treatment design is majorly decided based on the severity of the speech impairment such as articulation, resonance, speech understandability and voice disorders.

2.1 Speech Characteristics in VPD

In individuals with VPD, the inadequate closure of velopharyngeal valve causes an inability to efficiently accomplish the management of air stream for the production of speech. The speech characteristics provide the most important diagnostic information for assessing velopharyngeal function. The speech characteristics that reveal information about VPD are divided into active and passive characteristics. The passive characteristics are produced due to the structural abnormalities or dysfunction which includes audible nasal air emission accompanying obstruent consonants, weak obstruent consonant production, substitution of nasal consonants for oral sounds, hypernasal resonance distortion (Harding & Grunwell, 1998; Trost- Cardamone, 1990). The speech characteristics that suggest learned and compensatory behavior such as maladaptive posterior placement and voice deviations due to laryngeal hyper function in VPD are considered as active speech characteristics (Harding & Grunwell, 1998; Trost- Cardamone, 1990).

2.1.1 Passive speech characteristics

2.1.1.1 Hypernasality

Hypernasality is a category of resonance disorder that occurs when there is an abnormal coupling between nasal and oral cavities during speech production. The hypernasality is associated with the voiced sounds and does not affect the voiceless consonants (Cassassolles et al., 1995). Hypernasality is mostly seen in the vowels because all vowels are voiced and of longer duration. Andrews and Rutherford (1972) studied the perception of hypernasality in vowels. They found that the hypernasality is perceived more in high vowels than with the low vowels. This is because of the tongue which is placed high in the oral cavity during the production of high vowels which reduces the oral resonance and resulting in increased perception of hypernasality. The most common cause of the hypernasality is the VPD and it occurs due to the inadequate closure of the velopharynx during the speech production (Kummer, 2001). Warren (1997) indicated that speech is often judged to be hypernasal when the durations of the velopharyngeal opening and closing movements prior to and after a nasal consonant are too long.

2.1.1.2 Nasal Air Emission

Nasal air emission refers to the inappropriate release of the air pressure through the nasal cavity during speech production. It is a audible high frequency sound that occurs usually on pressure consonants as these sounds are required to build up adequate oral pressure. Nasal air emission occurs as a result of incomplete velopharyngeal closure. The nasal air emission is associated with the emission of air pressure and airflow thus affecting the articulation (Kummer, 2001). The other two forms of the nasal emission are the nasal rustle or turbulence and nasal snort which are result of the loud and the distracting sound.

Warren, Wood and Bradley (1969) opined that nasal turbulence can occur when there is a high airway restriction. The restriction may be due to the nasal congestion, inadequate velopharyngeal closure, and nasal obstruction. Mason and Grandstaff (1971) stated that nasal rustle or turbulence is a fricative sound that occurs when the velopharyngeal valve is partially restricted. When the valve is partially opened the air rushes through the valve and it becomes turbulent. Kummer, Curtis, Wiggis, Lee & Strife (1992) stated that nasal rustle occurs due to smaller velopharyngeal opening which results in the higher restriction of airflow. The other form of the nasal emission is the nasal snort which is the forcible emission of air pressure during the production of consonants. It results in the noisy sneeze like sound and mostly in the /s/ sound and also associated with other sibilants (Kummer, 2001).

2.1.1.3 Weak consonant production

The VPD results in the escape of the air pressure through the nasal cavity during the production of oral consonants. Because of this the air pressure that is necessary for the production of oral consonants is not adequate which results in the production of weak consonants (McWilliams et al., 1990). Therefore greater the nasal air emission the weaker the oral consonants. Further the higher nasal air emission results in the reduced length of the utterance.

2.1.1.4 Nasalization of oral consonants

Nasalization of oral consonants is an obligatory error which results due to moderate to large opening of velopharyngeal valve. During the production of voiced plosives in individuals with VPD the inadequate closure results in nasalization of the plosives and the plosive is substituted by the nasal consonants (m/b, n/d, ng/g). The placement of the articulation is same but the manner of articulation gets changed from oral to nasal due to the opening of velopharyngeal port.

2.1.2 Active speech characteristics

2.1.2.1 Compensatory articulatory production

The compensatory articulatory productions are altered production of the individual who has inadequate intraoral pressure for normal articulation. Here the manner of articulation remains unaltered and only the place of articulation is moved posteriorly towards the pharynx. The most common compensatory articulatory productions seen in individuals with VPD are glottal stops, pharyngeal stops, pharyngeal fricatives, generalized backing (Kummer, 2001). Glottal stop is a stop consonant which is produced at the level of glottis. It is produced with the forceful abduction of vocal folds and the build-up of air pressure under glottis. These sounds are produced with a rapid onset time and are substituted mostly for voiced plosives and also substituted for fricatives and affricates. The glottal stops are the most common backing errors produced by persons with cleft lip and palate (Peterson-

Falzone, 1989; Trost-cardamone, 1990). Henningson and Isberg (1986) found that limited or no velopharyngeal movement may be associated with production of glottal stops substitution and it may be co-articulated with oral stops.

The pharyngeal plosive is a consonant that is produced with the back of the tongue against the pharyngeal wall. During this production the entire tongue moves posterior and touch the pharyngeal wall and uses the air pressure in the pharynx before it losses through the velopharyngeal valve. Trost (1981) described the production of pharyngeal stop as a linguapharyngeal stop substitution for /k/ and /g/. The author noted that the location of this stop is influenced by the phonetic context in which it occurs. The pharyngeal fricative is a consonant that is produced with the back of the tongue and the pharynx. During this production the entire tongue moves posterior but does not touch the pharyngeal wall but makes a constriction between the base of the tongue and the pharynx resulting in forcing the air pressure through the narrow opening between the tongue and the pharyngeal wall producing a friction sound (Morley, 1970; Trost, 1981). The pharyngeal fricatives can be substituted for fricatives and affricates and are usually substituted for sibilant sounds. Morely (1970) distinguished between pharyngeal and glottal fricatives. The pharyngeal fricative involves the use of friction between the back of the tongue and the pharyngeal wall. The glottal fricatives are produced with increased tension in the vocal cords.

The posterior nasal fricative is a compensatory articulation characterized by audible nasal air emission and fricative (Trost, 1981). This compensatory articulation is produced as a result of the VPD. This sound can be substituted for any type of the pressure sensitive phonemes and it is typically substituted for sibilant sounds (Harding & Grunwell, 1998). It may be produced with or without turbulence. The turbulence form is also called as nasal rustle (Kummer et al., 1992) and a nasal snort (Morley, 1970). The generalized backing of phonemes or the palatalized articulation is seen commonly in individuals with VPD (Ainoda, Yamashita, &Tsukada, 1985). This is seen when the individuals produce most of the phonemes with the back of the tongue and pharyngeal wall. During the posterior articulation the tongue can push the velum upward to assist in closure. It is a form of compensatory articulation seen among individuals with VPD (Mc Williams et al., 1990). This generalised backing of the sound can be substituted for all the sounds.

2.1.2.2 Dysphonia

Children with the history of the cleft palate or VPD have an increased risk for the Dysphonia. (D'Antonio et. al, 1988). The authors investigated laryngeal and phonatory characteristics in 85 individuals with deficits in velopharyngeal valving in the age range of 3 to 52 years. The results showed that 71% of individuals had vocal nodules and 58% of the individuals had elevated subglottic pressure. The authors concluded that increased respiratory effort may be a factor for formation of vocal nodules in some individuals. A soft voice or low phonatory intensity are reported to be common findings in VPD (McWilliams, Morris, & Shelton, 1990). Bzoch (1979) indicated that the aspirated voice is used as a compensatory strategy for velopharyngeal insufficiency and to improve the intelligibility.

2.2 Assessment of Speech in Individuals with VPD

2.2.1 Perceptual Assessment

The speech evaluation in individuals with VPD can be classified under two major categories such as perceptual and instrumental assessment procedures. Perceptual assessment of speech plays a crucial part in the diagnosis of VPD, along with physical examination and clinical history (Trindade & Trindade Junior, 1996; Kummer, Briggs & Lee, 2003). The perceptual evaluation of resonance in individuals with VPD is mainly focused on identifying, for the presence or absence of hypernasality, nasal air emission and compensatory articulation during speech. It is also helps in rating the velopharyngeal function. Various procedures used for perceptual assessment include the use of rating scales to measure the speech characteristics such as hypernasality, audible nasal air emission, phonetically transcribing the speech samples for analysing articulation errors, speech intelligibility and use of qualitative descriptions.

2.2.1.1 Articulation

There are several articulation tests developed in English for screening and detailed assessment of the speech and the resonance characteristics in individuals with VPD. The Iowa pressure articulation test (IPAT) is a section of Templin Darley Tests of Articulation (Templin & Darley, 1969). This test consists of 43 high pressure consonants (plosives, fricatives, affricate sounds) necessary for evaluating the nasal air emission. Another test is Bzoch Error pattern Diagnostic Test (Bzoch, 1979) which includes plosives, fricatives and affricates which are affected in individuals with VPD. The articulation errors that may occur are obligatory errors, compensatory errors, placement errors, phonological errors, or developmental errors (Kummer, 2001). The scoring of the articulation test is done by using the phonetic diacritics from International Phonetic Alphabet (IPA) (Bronsted et al., 1994). The various diacritics symbols for the compensatory articulations were proposed by Trost – Cardamone (1997).

Van Denmark and Swickard (1980) noted that IPAT contains many consonants that are not acquired by 3 and 4 years of age and they suggested a test that emphasis /p/ and /b/ sounds. They suggested that these sounds are useful in discriminating young children who require secondary speech surgery and those who do not. The authors developed a set of words, pictures which aimed in identifying the VPD. It is a most appropriate early screening tool for children with limited consonant repertoires. The observation of error patterns are more important than the scores obtained from the test for differentiating the disordered articulation associated with VPD.

2.2.1.2 Nasal Air Emission

The nasal air emission can be evaluated as a part of the articulation test. The audible nasal air emission has to be distinguished between different types of nasal turbulence or a nasal snort (Kummer, Curtis, Wiggs, Lee, & Strife, 1992). The consistency of the nasal air emission has to be assessed. If the nasal air emission occurs on all the pressure sensitive phonemes it is considered as consistent. And if it occurs on only specific phonemes it is known as phoneme specific nasal air emission. The phoneme specific nasal air emission can be easily identified through perceptual evaluation alone and treated with speech therapy. The nasal air emission has to be assessed in connected speech because many individuals were able to achieve velopharyngeal closure for short utterances and not for sentences. Determining the presence of nasal air emission in individuals with palatal fistula is a complex procedure for the clinician. When the nasal emission occurs on anterior pressure consonants, the clinician should look for anterior palatal fistula. A posterior palatal fistula may be present when the nasal air emission is restricted to /k/ and /g/. Karling, Larson and Henningsson (1993) reported that obturating a fistula results in improving the velopharyngeal valve function. The clinician should attempt to identify the inaudible nasal air emission by placing a mirror under the nares of the individual and investigate the presence of condensation on the mirrors during the production of pressure consonants.

Pegoraro-Krook (2006) investigated the relationship between mirror test results and clinicians rating of hypernasality. They reported a sensitivity of 98% and a specificity of 71%. This indicates that although the mirror test gives some false negatives (2%), it has a high rate of false positives. The mirror test can be used effectively but the clinician should be careful in placing the mirror and taking the measures during the production of pressure consonants. The other devices with similar purpose and similar limitations are listening tube (Blakely, 2000) and the see scape.

2.1.2.3 Resonance

The evaluation of the resonance is done during the connected speech. The resonance can be perceptually judged as normal, hypernasal, hyponasal, and cul-de-sac resonance. The equal appearing intervals scales (EAI) for perceptual assessment of the resonance are widely used (McWilliams, Morris, & Shelton, 1990). The other scales such as direct magnitude estimation was recommended alternative to EAI scale (Whitehill, Lee & Chun, 2002) for research purpose. Universal parameters for reporting speech outcomes were recently described by Henningsson et al. (2008). Although they use the binary system for evaluation, a four point severity rating scale was used to rate the severity of hypernasality.

The correlation between the perceived degree of hypernasality and the velopharyngeal opening is reported to be poor (Kummer et al., 1992). This may be due to many factors such as compensatory articulation productions, audible nasal emissions. The supplementary tests are necessary for correctly diagnosing the resonance disorders. These supplementary tests are grouped under auditory, visual and tactile detection. In auditory detection, the cul-de-sac test (Bzoch, 1979, 1997) is used to assess the hypernasality, hyponasality and nasal emission. The devices which supplement the auditory perceptual judgement of the nasal air emission are stethoscope, straw and listening tube. The visual detection of the nasal emission is done by using a dental mirror, See Scape device (Pro Ed, 1986.Austin Texas) and Air paddle (Bzoch, 1979). The tactile method of judging the nasal emission is done by placing the index finger at the sides of the nose and as the individual repeats the pressure consonants the nasal emission can be felt through the vibrations.

2.2.2 Instrumental Assessment

The instrumental evaluation of speech includes indirect assessment and direct visualization techniques. Nasometry is an indirect computer-based procedure that provides information regarding the acoustic analysis of velopharyngeal function. Nasometer provides nasalance value (in percentage) that reflects the relative amount of nasal acoustic energy in a subject’s speech (Dalston, Warren & Dalston, 1991). Excessively high nasalance scores typically reflect hypernasality, while excessively low scores typically reflect hypo-nasality or de-nasality. The most widely used instrumentation for direct visualization of velopharyngeal function was videofluoroscopy and Nasoendoscopy in real time (Poppelreuter, Engelke & Bruns, 2000). Nasoendoscopy is also known as nasopharyngoscopy is an invasive endoscopic technique used for the evaluation of VPD by direct visualization of the velopharyngeal mechanism. The Nasoendoscopy is considered as the golden standard for evaluation of VPD because it allows the direct visualization of velopharyngeal mechanism and when compared to videofluoroscopy it is better in assessing the degree of velar movement (Lam et al., 2006).

2.2.2.1 Nasometry

Nasometry is a computer-based procedure that provides acoustic information regarding the velopharyngeal function. The Nasometer II (Kay Elemetrics, Model 6400) is an excellent tool for the assessment of resonance disorder. It consists of microphones on either side of a horizontal sound separator plate that rests on the upper lip. The microphone exactly below the nostrils is for picking up the nasal energy and the one near the mouth is for picking up the oral energy. Nasometer provides nasalance score that reflects the relative amount of nasal acoustic energy in a subject’s speech (Dalston, Warren & Dalston, 1991). Excessively high nasalance score typically reflect hypernasality, while excessively low score typically reflect hypo-nasality or de-nasality.

Since the Nasometer was introduced in 1986, several articles have appeared in the literature on developing the normative data in various languages. These studies indicated that nasalance scores vary across languages (Anderson, 1996; Van Doorn and Puecell, 1998; Van Lierde, 2001; Whitehill, 2001; Nandurkar, 2002; (Sunitha, Roopa & Prakash, 2004; Sweeney, Sell & O'Regan, 2004; Jayakumar &Pushpavathi, 2005). In Indian context, Sunitha et al. (2004) established the normative data in Tamil speaking individuals. In the first phase, ten meaningful sentences using the various sound classes in Tamil were developed. The subjects considered for the study were 120 typical developing children (60 boys and 60 girls) in the age range of 5 to 15 years. They were instructed to repeat the sentences and the data was analyzed using the Kay Nasometer (Model 6500). The results indicated that girls showed higher nasalance value than boys. The results revealed that the normative data for oral stimuli was 9-15%, nasal stimuli were 58-62% and predominately oral stimuli had 20-40%. The nasalance cut-off ranged between 13% and 17% across the gender and age for Tamil language.

Jayakumar and Pushpavathi (2005) studied nasalance values in 50 children (25 boys, 25 girls) with a mean age 8.1years) years and 50 adults (25 males, 25 females) with a mean age of 26.1years. The subjects were asked to repeat eight oral sentences and eight nasal sentences. The Nasometer II 6400 was used for the data collection and analysis. The results revealed that significant difference was evident across gender in adults. In males, for nasal sentences the nasalance value was 48.27 % (8.74) and for oral sentences 8.77 % (4.76). In females, for nasal sentences the nasalance value was 58.22 % (8.40) and for oral sentences 14.69 % (5.86). No significant difference was found across gender for children group.

An initial step towards refining the use of nasometry as an objective measure of perceived nasal acoustic energy involves manipulating the speech sample used. Several speech sample materials and reading materials (Rainbow passage, zoo passage) are reported to be useful in identifying individuals with VPD. Traditionally long passage such as zoo passage was used to assess nasalance. This paragraph contains a variety of oral consonants (plosives, fricatives, glides). The zoo passage has 83 syllables in length and presumably it is sufficiently long to obtain valid and stable measures of nasalance.

The most extensive literature on the nasometer's validity had typically displayed high levels of association between listener's perceptual findings and measures made by the instrument (Flectcher, 1978; Dalston and Warren, 1986; Hardin, Van Denmark, Morris & Payne, 1992). In addition to studies focusing on a straight clinical usefulness of Nasometer measurements, there have been researches into factors that affect the nasalance measures in normal speech. These studies indicated that nasalance values obtained from a typical individual is subtle to phonetic structure of the speech stimulus (Watterson et al., 1996), native language (Anderson, 1996), age and gender (Van Lierde et al., 2001). However, the findings are not universally consistent.

Dalston et al. (1990) found that an increase of 0.10 sq. cm velopharyngeal area which was aerodynamically determined resulted in the increased nasalance score for zoo passage. The nasalance score were notedly 32% higher than the normative data. The increased nasalance value correlated with the perceptual judgement of mild to moderate hypernasality. Another frequently used material is Rainbow passage, which consists of 11% nasal consonants and it is thought to signify the percentage of nasal consonants is typically seen in a conversational speech (Fletcher, Adams, & Cutcheon, 1989; Dalston & Seaver, 1992). Dalston and Seaver (1992) reported poor association between perceptual assessment of nasality and the nasalance values obtained on a rainbow passage.

Lewis, Watterson and Quint (2000) investigated the nasalance values obtained from with nine different speech stimuli by controlling the vowel content. The subjects selected for their study were 19 children with VPD and 19 typically developing children. The stimuli consisted of four sustained vowels and five sentences. One sentence was limited only to use of high front vowels; one confined to only high back vowels and so on. The result showed that in typically developing children, sentences and sustained vowels produced with high vowels were associated with significantly higher nasalance values than the sentences that used low vowels. The change was also noticed among front / back vowel differences. These normal alterations in oral and nasal sound intensity would also describe the increased nasalance on high vowels in individuals with VPD. However, nasalance values may vary depending on the vowel content of the speech stimulus.

Overall the speech samples influence the nasometer results. Sentence repetition is considered to be an efficient method of obtaining speech sample in children (Scherer & D'Antanio, 1995). In the evaluation of speakers with nasality and audible nasal air emission, Karnell (1995) suggested the use of distinct sentences loaded with high-pressure consonants and sentences including low-pressure consonants for measuring the nasalance values. He indicated that when nasal emission is present, nasalance values obtained on high- pressure consonant sentences might be overly high. The increase of nasalance values on high-pressure consonant sentences may become evident in individuals with nasal air emission, nasal turbulence, or both if separate nasalance values are acquired from high-pressure consonants and low-pressure consonant sentences. Sweeney et al. (2004) reported that separate analysis of the high-pressure and low-pressure category nasalance values may provide the information needed for differential diagnosis regarding hypernasality and nasal airflow errors, but the findings of the study was not well established.

2.2.2.2 Nasoendoscopy

Nasoendoscopy is also known as nasopharyngoscopy which is an invasive endoscopic technique used for the evaluation of VPD by direct visualization of the velopharyngeal mechanism. Nasopharyngoscopy equipment includes a durable and flexible fiber optic endoscope which has an increased number of fiber optical elements, which significantly enhances the resolution. Anatomical features, including small capillaries, can be observed in finer detail and with more clarity. The diameter of the scope can vary from between 2 mm to 4 mm. The 3.5-mm scope is commonly used since it is easily tolerated by most individuals, including children, and it provides a wide scope of vision. The end of the scope is very flexible and can be bent or turned easily without distorting the image. The body of the instrument, which is held in the examiner's hand, consists of an eyepiece and a control apparatus with a lever. The control apparatus (lever or wheel) allows the examiner to move the tip of the scope up and down like a periscope. The scope has a cable that is plugged into a high-intensity halogen light source with adjustable brightness. A light source is necessary for visualization of the structures. A special cold light source is used so that the light can travel through the scope without burning the individual as it reaches the pharyngeal area.

The nasoendoscopy procedure involves the use of nasal decongestion to desensitize the nasal cavity and the subject is seated in an upright position facing the examiner. The endoscope is slowly guided into the nasal meatus and back to the nasopharynx and it periscopes down to view the velum. A high resolution monitor attached to the control provides the examiner a better view and to see the exam in real time as it is done. For recording, a microphone is attached to the individual so that the speech recording is of good quality. The recording is very useful because it can always be viewed again for further analysis. The Nasoendoscopy is considered as the golden standard for evaluation of VPD because it allows for the direct visualization of velopharyngeal mechanism and when compared to videofluoroscopy it is better in assessing the degree of velar movement (Lam et al., 2006). Flexible fiberoptic nasopharyngoscopy is now commonly used in clinical settings for the evaluation of VPD. Nasopharyngoscopy provides a view during speech of the nasal surface of the velum and all of the structures of the velopharyngeal valve. Nasopharyngoscopy results are complementary to radiographic studies.

2.2.2.3 Videofluroscopy

Videofluroscopy is a procedure in which the subject is positioned between the fluoroscope and the image intensifier and is comfortably seated in a normal upright position with the head held stable by some type of head rest, the obtained x-ray image is amplified by the electronic intensification, making it bright enough to be recorded in the video camera. The multiview Videofluroscopy was first introduced by Skolnick (1969) which allows the recording of the radiographic images on the videotape. Kummer et al. (1992) stated that it is a technique that will provide a comprehensive view of the velopharyngeal mechanism by using several projections. It is a radiographic procedure that allows imagining of velopharyngeal port during speech, through the use of several two dimensional views such as frontal, basal and lateral view (Kummer, 2001). The front view also known as anterior-posterior view which shows the lateral pharyngeal walls at rest and speech. The lateral view shows the velum and posterior pharyngeal walls and the base view shows the entire velopharyngeal port. The contrast materials such as a liquid radiopaque material, barium sulphate clearly outline the structures of interest and are commonly used for clinical purpose.

Neely and Bradley (1964) developed a psychophysical rating scales to establish the standard procedures for the analysis of videofluroscopic images. The variables that they included for rating are the approximation or the contact between the velum and the posterior pharyngeal wall, thickness of the soft palate, length of the soft palate, extent of the vertical contact between the velum and the posterior pharyngeal wall, location of velopharyngeal closure relative to the anterior –most projection of the tubercle of the first cervical vertebra, location of the closure relative to the hard palate. The ratings made by 16 judges were analyzed in terms of percentage of agreement between two ratings. Most of the correlations were in the 0.7 and 0.8. The percentage of agreement ranged from 38% to 81%. The authors concluded that the rating scales provide consistency in the observations made and judges should be trained with the rating procedures.

Golding-Kushner et al., (1990) reported the results of international working group which was formed to establish standards for reporting videofluroscopic data and videoendoscopic data. Their system was based on relative ratings or measurements. Displacement of structures was considered relative to the position of the structure at rest and the maximum position to which the structure could move. This system was attractive because it has both research and clinical utility. The measures was obtained from video screen from the digital images using digital video processing which can be used for research purpose and for clinical purpose rather than precise measurements clinical judgements can be used.

2.2.2.4 Magnetic Resonance Imaging (MRI)

Magnetic Resonance Imaging scans (Ettema, Kuehn, Perlman, & Alperin, 2002; Ha, Kuehn, Cohen &Alperin, 2007; Atik et al., 2008) have been applied to velopharyngeal research and may eventually become sufficiently evolved and affordable to routine clinical evaluation of the velopharyngeal mechanism. MRI is based on property of protons to receive and transmit electromagnetic energy when placed in a magnetic field. The number of protons in a given tissue determines, in part, the strength of the transmitted energy to form an MRI Image. MRI is well suited to image soft tissue especially velopharyngeal mechanism. A major limitation of MRI is the recording of motion images of velopharyngeal structures during the production of speech (Kane, Butman, Mullick, Skopec, & Choyke, 2002). Most of the studies that have used the MRI for imaging the velopharyngeal structures were by recording the still images during sustained phonation. Other researchers (Ettema et al., 2002; Ha et al., 2007) used MRI to describe the at rest muscular anatomy of velopharyngeal structures in individuals with and without clefts. Rowe and D' Antonio (2005) admitted that application of MRI will provide useful new information and ultimately be as effective as other techniques such as videonasoendoscopy and Videofluroscopy.

2.2.2.5 Dysphonia Severity Index (DSI)

The objective measure of voice quality evaluates various acoustic parameters of voice. The previous studies have reported that not all the acoustic parameters of voice correlate well with the perceived voice quality (Heman-Ackah, Michael, & Goding., 2001; Munoz et al., 2003; Heman-Ackah, Heuer, & Michael, 2003). A multiparametric approach was developed which uses a combination of several acoustic and aerodynamic parameters to correlate with the perceived voice quality. Dysphonia severity index (DSI), one of the multiparametric approaches for objective measurement of voice quality was developed by Wuyts et al. (2000). The author considered several acoustic and aerodynamic parameters such as Jitter (%), Shimmer(%), Noise to Harmonic Ratio (NHR), Highest frequency (F_0-High) (Hz), F_0-Low (Hz), F_0-Range (Hz), Semitone-range, Lowest Intensity (I-Low) (dB), I-High (dB), I-Range (dB), maximum phonation time (MPT), Vital Capacity (VC) and Phonation Quotient (PQ) (cc/s) to calculate the weightage of each parameter on perceived voice quality. On analyzing these entire variables on normal and disordered population, the author derived the index consisted of weighed parameters such as maximum phonation time (MPT), highest fundamental frequency (F_0 -high), lowest intensity (I-low), and jitter (%). The DSI is constructed as DSI = 0.133 * MPT + (0.00533 * F0-High) - (0.263* I-Low) - (1.183* Jitter %) + 12.4.

The DSI can be obtained easily and quickly by speech pathologist in a clinical setup. The DSI is very useful in evaluation of individuals with voice problems. The resulting DSI values vary between $\geq$ +5 (No dysphonia) and < –5 (severe dysphonia). Since the range of possible scores on the separate parameters is wide, scores + 5 (good voice quality) or - 5 (poor voice quality) are possible as well (Wuyts et al., 2000). DSI is not limited to the interval +5, –5. In clinical practice values of –6 and more are also reported. This is generally caused by high jitter values.

Van Lierde, Claeys, De Bodt, & Van Cauwenberge (2004) examined the vocal quality and effect of vocal quality on gender in children with CLP. Twenty eight children with unilateral or bilateral cleft lip and palate were considered for the study. The voice quality was measured using the videolaryngo stroboscopic and perceptual evaluations, acoustic measures, aerodynamic assessment, voice range profile, and dysphonia severity index (DSI) measurements. The results showed that vocal quality differed across gender, the male children showed an overall vocal quality of +0.62 with slighter degree of hoarseness and female children showed +2.4 indicating a perceptually normal voice. The authors concluded that the results of the study conveyed valuable evidence on the vocal quality characteristics of children with cleft palate.

Van Lierde, Bonte, Baudonck, Cauwenberge and De Leenheer (2008) studied the speech outcome on voice characteristics post-operatively following pharyngeal flap surgery in seven subjects in the age range from 4.7 to 9.1 years with a mean age of 6.9 years. Dysphonia severity Index (DSI) was calculated in subjects postoperatively after one year. The stroboscopic evaluation for vocal outcome showed normal vocal folds. The results showed that overall vocal quality of the DSI was 1.7 (range 0–4.8) reflecting, as very slightly impaired vocal quality. These results may be hypothesized due to the stronger adductory force on the vocal folds to minimize hypernasality and to reach specified voice intensity.

2.3 Comparison of velopharyngeal closure and perceptual speech characteristics in individuals with VPD

The perceptual, structural, physiological characteristics of the velopharyngeal mechanism and the 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 reported that the relationship between the perceived degree of hypernasal resonance and size of the velopharyngeal gap is non-linear. 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 velopharyngeal valve is open (Dalston & Seaver, 1990; Warren et al., 1993), and the speaker's articulatory compensations for the velopharyngeal opening (Watterson & Emanuel, 1981; Folkins, 1985).

Kummer et al. (1992) conducted a study to investigate the relationship between velopharyngeal gap size and perceptual speech characteristics of individuals with VPD. 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 were correlated with perceptual parameters. The results of their study 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 speculated to be related to velopharyngeal gap size. Based on the differences, it was concluded that individuals with 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, Briggs, and Lee (2003) further studied the relationship of velopharyngeal gap size and characteristics of speech in individuals with VPD secondary to cleft lip and palate. They studied 173 children retrospectively in the age range of 3 to 12 yrs. 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 et al., 1989). The results indicated 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 is associated with greater velopharyngeal gap and the nasal rustle associated with lesser gap.

Dudas, Deleyiannis, Ford, Jiang and Losee (2006) studied the effective perceptual speech characteristics which can predict the velopharyngeal closure. Twenty four children with VPD were included in this retrospective study who had undergone 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 subscore 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 mentioned studies mostly dealt with the study of perceptual speech characteristics such as hypernasality, phonation and nasal air emission's prediction on velopharyngeal anatomy and function. The subjects considered in the studies were individuals with VPD secondary to repaired cleft palate and further they were grouped based on their speech characteristics.

2.4 Management of Individuals with VPD

The VPD exhibits itself in different ways in different individuals. The management options are not easily decided for all individuals with velopharyngeal dysfunction. Some individuals may demonstrate evidence of VPD but may not be a suitable candidate for treatment options other than speech therapy. So the management options may differ for different individuals which have to be monitored over time. For some individuals with VPD working on the articulation will reduce the perceived nasality in that individual's speech and at this point of time surgical or prosthetic management are not necessary. The presence of hypernasality and nasal air emission in an individual does not necessarily mean that the individuals should be referred for surgical management. The severity of the problem, its impact on speech intelligibility, the child's and parent's reaction to the problem and their motivation should be taken into consideration while recommending for a management option.

2.4.1 Non –surgical management of VPD.

The non-surgical management of VPD is grouped into two categories one is the speech therapy and the other is the prosthetic management of VPD.

2.4.1.1 Speech Therapy for VPD

The speech therapy is commonly considered for individuals with mild VPD and these individuals are characterized by phoneme specific, intermittent, occurs due to fatigue and it is mostly accompanied by inappropriate articulation and oro motor dysfunction. And speech therapy is essential to treat the compensatory articulation errors that are persistent after the surgical management of VPD. The speech therapy is mainly focused on correction of the articulation and resonance problems of individuals with VPD. The speech therapy is not appropriate for individual with VPD caused due to structural defects such as obvious palatal defects such as cleft of soft palate and submucous cleft palate. These individuals are recommended for speech therapy after surgical correction of VPD. The individuals who were eligible for speech therapy are recommened with different techniques depending on various factors such as age, cause, severity of VPD, phonetic inventory, expressive vocabulary and active participation of the family member in the therapeutic program. The selection of the appropriate therapy techniques depends on the careful evaluation of the individuals with VPD by an experienced speech language pathologist.

The compensatory articulatory errors are common in individuals with VPD. These errors have a greater impact on the speech intelligiblity and resonance characteristics of individuals with VPD (Tonz et al., 2002). The primary goal of articulation therapy involves teaching appropriate place and manner of articulation (Michi, Suzuki, Yamshiata & Imai, 1986). These can be achieved by using auditory, visual and tactile feedbacks during the production of target consonants. Resonance therapy involves the use of auditory feedback devices such as see-scape, nasal stethoscope and endoscopic feedback to improve the inappropriate nasality caused due to VPD. Therapy techniques may include oro-motor awareness, continuous positive air pressure (CPAP) and biofeedback techniques for improving nasality in individuals with mild VPD.

2.4.1.2 Prosthetic Management in VPD

The prosthetic management of VPD involves the use of palatal lift and speech bulb devices made up of dental acrylic materials. The palatal lift prosthesis helps to lift the soft palate up and back to touch the posterior pharyngeal wall and speech bulb prosthesis is used as an obturator to assist the residual palate in the velopharyngeal closure. These prosthesis devices can be removed at night and it is helpful in individuals with airway disorders. The prosthetic devices have some disadvantages in children because of presence of deciduous teeth, the expansion of maxilla due to development which affects the retention of the device. Hence, these prosthetic devices are more appropriate in adolescents and adults who did not achieve a successful outcome following surgical intervention.

2.4.2 Surgical management for VPD

VPD is one of the most common conditions occurring secondary to cleft palate. Although the occurrence of VPD following cleft palate repair may differ with severity of cleft, age of surgery, type of technique, , and experience of the surgeon , about 10 to 25% of individuals with cleft palate will eventually need secondary surgical correction (Krischner & Ruotolo, 2006). In the majority of such individuals, the underlying cause of VPD is velopharyngeal inconsistency, poor velar function, or a combination of the two. Randall, LaRossa and McWilliams (2000) revealed an inverse association between velar length after palatal repair and the need for secondary surgical correction of VPD. All individuals who have undertaken cleft palate repair need careful longitudinal evaluation of velopharyngeal function. Even mild perceptual indication of VPD documents need for detailed assessment. The importance of normal speech for socialization and ideal quality of life cannot be overstated, and the selection of best procedure for palatal repair should be considered successful is that which restores both normal palatal structure and normal palatal function for speech.

The surgical correction of the VPD is required following a primary palatal repair due to the scarring which may shorten the velum or abnormal muscle insertion or neuromuscular dysfunction. If the problem is anatomical or neurological, the correction involves augmentation into the velopharyngeal opening to reduce the size of the gap for proper velopharyngeal closure. The auditory perceptual evaluation of the individual’s speech by speech language pathologists is critical for deciding upon whether surgical correction is required for VPD. The surgical correction can be done as early as 3 to 4 years of age as connected speech develops at this age which is essential for evaluation of VPD.

The surgery for VPD is mainly classified into two categories. The first category being palatal surgery, where there is a modification of soft palate alone and other group of surgeries involves the modification of pharyngeal walls and these procedures and termed as pharyngoplasty. The palatal surgery procedures include levator muscle reconstruction procedures, Intervelar veloplasty and Furlows double opposing Z plasty. The pharyngoplasty procedure includes pharyngeal flap, Sphicter pharyngoplasty and augmentation pharyngoplasty. Witt et al.(1997) stated that most commonly performed secondary surgical correction are pharyngeal flap, sphincter pharyngoplasty, and other procedures in a selective manner in an attempt to more accurately match surgical treatment to the patient’s particular pathophysiology . The pharyngeal flap is designed to be a passive, soft tissue obturator that is placed in the middle of the velopharyngeal port. (Tharanon ,Stella ,& Epker,1990; Yoshida ,Stella ,Ghalli & Epker ,1992). Morris, Bardach, Jones, Christiansen and Gray (1995) reported that 83.1% of their 65 subjects achieved velopharyngeal function within normal limits following pharyngeal flap procedures and that 66.1% showed normal or near normal speech production.

2.4.2.1 Levator Muscle Reconstruction Procedures

The surgical procedures used for primary palatal repair to produce a soft palate with maximum possible length or closest approximation to normal muscle orientation. They are also used for secondary surgery in older individuals for whom the primary surgery did not produce good results. These procedures include intravelar veloplasty (Nakamura et al., 2003; Sommerlad et al., 2002) and the Furlow Z-plasty (Furlow, 1997; Noorchashm et al., 2006). Huang, Lee, and Rajendran (1997) urged the preservation of musculus uvulus during intravelar veloplasty and expressed concern that this muscle was incorrectly reoriented bu double opposing Z-plasty.

2.4.2.2 Intravelar Veloplasty

Kriens (1970) advocated the intravelar veloplasty for primary closure of the soft palate and it is based on findings that the fibers from the left and right levator muscle bundles do not join normally within the soft palate in children with cleft lip and palate. It is a procedure in which dissecting the levator bundles from their abnormal insertion and repositioning them to approximate the normal levator sling. Jarvis and Trier (1988) used intravelar veloplasty with pharyngeal flap as a secondary procedure in a group of 91 individuals with repaired cleft palate. The results showed that 77 of 91 individual's speech outcome improved. However, the authors found no difference in speech outcomes when compared with 38 individuals who received only pharyngeal flap surgery. They concluded that adding intravelar veloplasty to pharyngeal flap created no extra benefit to the clients.

2.4.2.3 Furlow Double Opposing Z-plasty

The main principle of furlow double opposing z plasty involves the rearrangement rather than transection of the palatal muscles. The palatal muscle was elevated as part of the posterior based flap of each Z-plasty. The posterior based oral mucomuscular flap was on the left side for a right handed surgeon. The nasal Z-plasty was made as the mirror image of the oral layer. The lateral limbs of the oral Z-plasty ended over the hamuli. The left cleft margin was cut first and the mucoperiosteal flaps were raised without any lateral relaxing incisions. Randall, LaRossa, Soloman and Cohen (1986) described that double opposing z-plasty was useful not only as a method for primary palatal repair but also a secondary palatal repair procedure, especially for individuals requiring additional palatal length or those benefit from repositioning the levator muscles. Furlow (1997) described it as a tool for lengthening the velum and constructing a functional palatal muscle. Thus this procedure is suitable for individuals with mild to moderate velopharyngeal gap.

Chen,Wu,Chen and Noordhoff (1994) reported that furlow procedure appeared to produce the best results for individuals with mild degrees of VPD for speech. They found that the procedure worked best with those will small (< 5mm) velopharyngeal gaps. Deren et al (2005) reported best speech outcomes in children with smaller preoperative gaps observed nasoendoscopically during speech. Perkins, Lewis, Gruss, Eblen and Sie (2005) reported a highly significant association between preoperative velopharyngeal gap size and post-operative speech outcomes in 148 individuals with velopharyngeal dysfunction. Post-operative VPI was categorized as none or minimal for 73% of the individuals who had small preoperative velopharyngeal gap. Only 19% of the individuals with larger pre-operative gaps had positive results. The advantage of levator reconstruction procedure is that they would approximately reproduce the velopharyngeal physiology that would have been in a normal structure. The complications of this procedure include bleeding, palatal fistulas and nasopharyngeal airway obstruction.

2.4.2.4 Pharyngeal Flap

The pharyngeal flap surgery is the most frequently used procedure to reinstate velopharyngeal function in which the muscles from the posterior pharyngeal wall are inserted to the palate to narrow the velopharyngeal opening. This helps in correcting the hypernasality and nasal air emission caused due to VPD (Ysunza et al., 2002). Pharyngeal flaps can be superiorly based or inferiorly based (Lideman-Boshki, Lohmander, Persson, Lith, & Elander, 2005). Among the types of pharyngeal flaps, inferiorly based flaps are limited in respect to the size of velopharyngeal opening that can be enclosed compared to the superior based flaps (Peterson-Falzone et al., 2001). The centrally placed pharyngeal flap is accomplished by surgically making a U-shaped incision at the midline of oropharynx, dissected away from the pharyngeal wall, is brought forward and inserted into an incision created on the nasal surface of the soft palate. This results in a midline bridge extending from the flaps attachment with the posterior pharyngeal wall to its point of insertion into the soft palate, with two open spaces on either side of the flap which helps in nasal respiration, drainage and resonance.

Morris and Spriesterbach (1971) reported that good speech outcome result from the flap surgery was dependent on the medial movement of the lateral pharyngeal wall or the superoposterior movement of the velum. Tonz et al. (2002) randomized the audio speech samples of 23 children recorded before and after pharyngeal flap surgery to a group of speech language pathologists and to a group of lay persons. The SLPs rated 83% as improved and the lay group rated 87% as improved. Armour et al. (2005) indicated that pharyngeal flap surgery is most successful for individuals with sagittal pattern of velopharyngeal closure and they also stated that when performed in young children , the speech impairments were tend to be lesser because of the earlier management which reduces the risks for development of compensatory strategies which further deteriorates the speech intelligiblity. The risks factors following flap surgery is the obstructive sleep apnea (Agarwal et al., 2003; Pena, Choi, Boyajian, & Zalzal, 2000). Morris et al. (1995) found that 89% of individuals who underwent pharyngeal flap procedure snored after surgery. These complications likely result from the narrowing of the airway, secondary to edema following surgery.

2.4.2.5 Augmentation Pharyngoplasty

Augmentation pharyngoplasty are attempts to bring the posterior pharyngeal wall forward, create the equivalent of an adenoid pad. The techniques that have been used are rearranging adjacent soft tissue, implanting cartilage or fat, injecting or implanting various types of synthetic materials. In soft tissue advancement, Hynes (1950) created an elevation on the wall by dissecting the salpingopharyngeus and its overlying mucosa, lifting these two lateral flaps and suturing them into a pocket he created on the posterior pharyngeal wall making an incision below the Eustachian tube orifice. Later the procedure was modified by including palatopharyngeus, salpingopharyngeus and a portion of superior constrictor. In cartilage implants, autogenous cartilage from the individual’s rib, was used to create an anterior projection or pad on the pharyngeal wall (Hagerty, Hess, & Mylin 1968).

Denny, Marks and Oliff-carneol (1993) used cartilage implants in 20 individuals with velopharyngeal gap measuring only 1 to 3 mm on radiographic studies. They reported normal resonance and articulation in five out of 20 individuals, some improvement in 11 and no change in four individuals. There were severe methodological issues in their study. Out of 20 individuals, seven of them were syndromic and the post-operative follow up was only 8 weeks. The authors stated that the size of the implant should be three times the size of the measured gap in order to have an effect. Dejonckere and van wijngaarden (2001) reported improved mean nasometric measurements in 17 individuals who received autologous fat implants who appeared to have mild VPD owing to congenitally short palate. The authors reported that nasometric data, and self-evaluation questioners responses confirmed benefit as long as 6 months. The nasalance measures improved from a preoperative nasalance mean of 35% to approximately 25%, a statistically significant difference. The increase in the size of the posterior pharyngeal wall is specified in individuals who have adequate movement of their soft palate and who have small gaps as indicated by preoperative imaging techniques such as cineradiographic and endoscopic evaluation. This technique might play a significant role in individuals who have been diagnosed to have borderline velopharyngeal dysfunction, individuals who had characteristics of VPD following adenoidectomy, and in those individuals who are considered to be at risk for obstructive sleep apnea after pharyngeal flap or sphincter pharyngoplasty. The augmentation pharyngoplasty is widely associated with the use of autologous tissue because no single alloplastic material has been found to be reliably safe and effective.

2.4.2.6 Sphincter Pharyngoplasty

This is one of the surgical techniques to correct the VPD. Orticochea (1970) dissected the posterior faucial pillars from their inferior attachments and the lateral pharyngeal wall and sutured them into the contralateral corners of posterior pharyngeal wall. In the immediate postoperative period this procedure creates a lateral defects where the posterior pillars were detached from the lateral pharyngeal wall. When these are healed, there is one small central sphincter that closes during speech. The author reported 89% success rate in 236 cases with a variety of etiological bases for their VPI. Losken, Williams, Burstein, Malick and Riski (2003) reviewed 250 individuals who received sphincter pharyngoplasty. The results reveled that improvements were seen in subjective and objective speech analysis performed before and after surgery. They reported that a success rate of 87% after initial pharyngoplasty and 99% after revision pharyngoplasty. Of the 32 individuals who required revision , 25 requiring tightening of the sphincter to address residual VPD and seven required sphincter expansion to address nasal airway compromise. As with other surgical approaches to secondary management of VPD accurate diagnosis of the problem is very important.

Kawamoto (1995) stated the outcome of sphincter pharyngoplasty by means of postoperative nasendoscopy which revealed that complete velopharyngeal closure in 89% of 18 individuals with VPD. The dynamic sphincter was achieved in only 67% of the individuals. Thus the author concluded that structural factors, such as reduction in velopharyngeal port size and increasing the size of the posterior pharyngeal wall, may play an significant role in surgical outcome. In contrast, Witt et al. (1997) evaluated pre- and postoperative videofluoroscopic assessment in twenty individuals who underwent sphincter pharyngoplasty, indicating that all individuals showed some dynamism, although there was a wide difference noted in the degree of muscular activity of the sphincter. The complications of this procedure involve obstructive sleep apnea, flap dehiscence and nasal airway restriction. The Sphicter pharyngoplasty is functionally more effective than posterior pharyngeal flap because it is less likely to cause airway obstruction.

2.4.3 Speech Outcome Studies after Secondary Surgery

There are few studies which are aimed to analyze the speech characteristics before and after secondary cleft palate surgery. These studies differ with respect to the selection of the subjects, method of assessment and surgical procedure used. Karling, Henningsson, Larson and Isberg (1999) compared the speech outcome between the two types of the pharyngeal flap surgeries such as transversely split (TS) velum flap and midline split (MS) velum flap. The subjects were alienated into two groups depending on the type of flap. The first group consisted of 22 subjects in the age range of 4 to 25 years who underwent transversely split velum flap at a median age of 7.5 years. The second group consisted of 20 subjects in the age range of 4 to 58 years in whom midline split velum flap was done at a median age of 10 years. The pre and post-operative assessment techniques included cineradiography, nasoendoscopy, cephalometry and perceptual speech evaluation judged by three speech pathologists. Nasal Oral Ratio Meter was used for acoustic analysis of subject's speech. The speech samples considered were repetition of high pressure CV syllables such as [pi: pi: pi:], [ki: ki: ki:], [ti: ti: ti:] and nasal vowel syllable [mi: mi: mi:] and short utterances include most of the vowels and high pressure consonants. A five point rating scale was used to judge the speech samples, in which one represents normal and five represents severe deviation from normal speech. The results revealed that in both groups there was a significant decrease in hypernasality, weak pressure consonants, nasal air escape and velar snort post operatively. In Midline split velum flap subjects, increase in the hyponasality was observed. The visualization procedures revealed increase in pharyngeal wall adduction in 17 individuals with VPD. There was significant difference between pre and postoperative pharyngeal wall adduction. The pre and post-operative scores of Nasal Oral Ratio Meter revealed that for MS flap group the hypenasality reduced from 28% to 10% and for TS flap group it reduced from 35% to 7%. Thus 93% of subjects achieved nasal percent within the limit for normal variation. This study highlighted the need of detail pre and post comparison of assessment using perceptual and instrumental evaluation.

Tonz, Schmid, Graf, Heeb, Weissen and Kaiser (2002) assessed the speech outcome after pharyngeal flap surgery in 23 children (mean age of 9.7 years) with VPD. The perceptual speech evaluation was performed for both pre-operative and postoperative conditions. These children underwent adenoidectomy 4-6 weeks prior to the pharyngeal flap surgery. The speech sample consisted of audio recording of spontaneous speech and they were randomly presented to the judges with mixed pre and post-operative conditions. The evaluators consisted of two groups; first group consisted of 3 speech language pathologists experienced in evaluating individuals with CLP and the other group consisted of seven third year medical students with no experience in the speech assessment. A five point rating scale was used to evaluate the speech characteristics such as hypernasality, hyponasality, nasal turbulence, intelligibility, articulation and voice. In addition, a binary scale (normal/ absent or abnormal /present) was used for each speech characteristics. The results showed decrease in nasality among 78 % of subjects, improved articulation in 87 % of the children and increased speech intelligibility in 83 % of the subjects. Also postoperatively, hyponasality was not observed. But significant improvement was noticed in articulation and speech intelligibility but not in the nasal turbulence or vocal quality. The results of the evaluation revealed that the success rate was 19 out of 23 individuals and it was not different from the success rate measures by the professionals. Thus authors concluded that cranially based pharyngeal flap surgery can improve speech performance in children with VPD. However, this study mainly focused on using only the perceptual method of assessment.

Ysunza, Pamplona, Ramirez, Molina, Mendoza and Silva (2002) compared the speech outcome of pharyngeal flap and sphincter pharyngoplasty surgical techniques in individuals with repaired CLP and residual VPD. 50 individuals with cleft palate associated with VPD with mean age of 4.7 years were randomly divided into two groups based on nasoendoscopy and Multiview videofluroscopic findings. 25 children in group I underwent pharyngeal flap surgery and 25 children in group II underwent sphincter pharyngoplasty, Pharyngeal flaps surgery was done for all the subjects. Preoperative and postoperative (4 months) assessment was done. The assessment protocol included was perceptual speech evaluation, multiview videofluoroscopy and videonasoendoscopy. The results showed that VPD was reported to be completely corrected in 89% of the individuals in the pharyngeal flap group and 85% of the sphincter pharyngoplasty group. The results also indicated that the size of the velopharyngeal gap reduced in all individuals 88% (22/25). Complete velopharyngeal closure was noticed in 3/25 but bubbling at the velopharyngeal sphincter during speech was observed. The post-operative perceptual speech characteristics showed significant reduction in the nasality and nasal air emission. The authors did not indicate the degree or type of residual VPI following surgery, or if any patients presented with post-operative hyponasality. The authors concluded that that modified pharyngeal flaps and sphincter pharyngoplasties done according to the findings of videonasoendoscopy and multiview videofluoroscopy are safe and reliable techniques for treating VPD in individuals with cleft palate.

Meek, Coert, Hofer, Goorhuis-Brouwer and Nicolai (2003) investigated the short-term and long-term speech outcome in 93 individuals with CLP after pharyngeal flap surgery for VPD. The mean age of subjects at the time of surgery was 5.5 years. Out of 93 individuals, 53 individuals underwent adenoidectomy six weeks prior to caudally based pharyngeal flap and the other 40 underwent adenoidectomy and cranially based pharyngeal flaps simultaneously. Pre-operative and postoperative (6 weeks, 6 months and 12 months) assessments were made for all the individuals. The assessment protocol included perceptual speech evaluation by using rating scales. The results showed that improvement was seen in parameters such as hypernasality, articulation, nasal emission and velopharyngeal function in all the subjects. The subjects who underwent treatment when they are less than six years improved better than the subjects who were older than 6 years at the time of surgery. No differences were seen between types of flaps that were considered in this study. The authors concluded that earlier surgery leads to better speech results in the long term follow up.

Cable, Canaday, Karnell, Karnell and Malick (2004) studied long term speech outcomes in 43 individuals with cleft lip and palate having VPD. Hogan technique was done for the all the individuals with the mean age range of 3.8 years. Postoperative assessments were carried out at 2–5, 5–8, 8–11, and 11–14 years. All the individuals who underwent pharyngeal flap surgery during 1970 to 2000 were identified for the study. Individuals who had a postoperative speech assessment which was done between 2 and 5 years after the surgery were finally selected for their study. The Perceptual speech assessment of hypernasality and hyponasality were done. Both the resonance parameters were evaluated on a six point rating scale, with 1 signifying no involvement and 6 indicating severe effect on resonance. Velopharyngeal closure was also rated on a three point rating scale, with 1 indicating complete closure and 3 indicating incomplete closure. The results revealed that resonance performance continued to be satisfactory and even found to improve as the patient continues to grow. The results of the study indicated that pharyngeal flap procedure to be acceptable management to correct VPD. The authors failed to describe what the word adequate refers to and the percentage of successful participants was not mentioned in this study. The major limitation of this study was that all the observations were based on subjective measures only. This finding implicates the use of the pharyngeal flap in the management of children with VPD.

Armour, Fischbach, Klaiman and Fisher (2005) studied the velopharyngeal closure patterns after superiorly based pharyngeal flap surgery in 93 individuals with repaired cleft lip and palate. Out of 93 individuals 42 had coronal closure pattern with a mean age at surgery was 9.3 years and 51 individuals with noncoronal closure with a mean age at surgery were 13.5 years. Superiorly based pharyngeal flaps were done for all the subjects. Pre-operative speech assessment was made six weeks prior to the surgery and postoperative speech assessment was made six weeks and one year after surgery. The speech assessment procedures include nasometry using the Mac Kay-Kummer Simplified Nasometric Assessment Procedure (4 sentences with oral pressure consonants and 1 nasal sentence). The results showed that nasalance during nonnasal speech were decreased on average, for all closure patterns, postoperatively. The 57% of noncoronal pattern group had normal nasalance values postoperatively compered to coronal group (35%). The results also revealed that both the closure patterns demonstrate an improvement in hypernasality at 6 weeks postoperatively and at 1 year postoperatively for oral sentences. The authors concluded that superiorly based flaps were more efficient in correcting sagittal or circular closure patterns of velopharyngeal closure. The individuals with coronal pattern of closure were effectively treated with Sphicter pharyngoplasty than pharyngeal flaps.

Abyholm et al. (2005) studied the speech outcome of individuals with VPD who underwent pharyngeal flap and sphincterplasty one year post operatively. Ninety seven subjects in the age range of 3 to 25 years old with repaired cleft palate and previously identified as VPD were enrolled from five centres in United States, Norway and United Kingdom. The data was collected at presurgery, 3 months, post-surgery and 12 months post-surgery for subsequent analysis of the procedure. The perceptual speech evaluation was obtained by a standardized protocol and phonetically balanced speech sample for each language which was video recorded. A four point rating scale was used for rating both hypernasality and hyponasality and was judged by three speech therapists. The nasometric evaluation was done using the syllables in the Simplified Nasometric Assessment Procedure (SNAP) by MacKay and Kummer (1993) which consisted of high pressure consonants /p/ and /s/ and the nasal consonants /m/ in combination with high and low pressure vowels /a/ and /i/. The nasoendoscopic evaluation was obtained using a standardized speech sample which was phonetically balanced for each language. The results showed statistically significant difference for perceptual speech evaluation between the two groups at 3 months post-surgery and elimination of hypernasal resonance in flap group. But, at 12 months post-surgery significant difference was not observed between the both groups on nasalance value and resonance, endoscopic outcomes. However, at 3 months follow up the reduction in the nasalance scores were noticed for three syllable stimuli for flap group. Even though this study utilized the perceptual and instrumental method, they had selected the wide age range. These results assist in the choice of surgery in individuals with VPD when there is a quick need for management is required.

Dailey, Karnell, Karnell and Candy (2006) aimed at evaluation of resonance outcomes after pharyngeal flap surgery and furlows double - opposing z- plasty in subjects with severe velopharyngeal dysfunction (VPI). They used a retrospective study in which authors reviewed total of 115 participants who underwent the surgical procedures from 1993 to 2002. Out of which 49 met the criteria of VPD and among them 24 subjects underwent Z –plasty and 25 subjects underwent pharyngeal flap surgery. The pre- and post-operative speech assessments included single word articulation test, sentence repetition, and spontaneous speech. The perceptual rating was done for hyponasality and hypernasality by a speech language pathologist using a six point rating scale. All the participants received endoscopic or fluoroscopic evaluations which were related for velar movement, posterior pharyngeal wall movement, lateral wall movement, and residual VP port size. The movement of the structures were rated as an estimation of percentage of VP gap that was closed during the attempts at closure. The velopharyngeal function was judged as competent, incompetent, or marginal according to considerations of both physical observations and perceived speech quality. The results showed that both pharyngeal flap and Z-plasty groups benefited by significant reduction in the perceived hypernasality from surgery. Postoperative hypernasality ratings were significantly lower than preoperative ratings for both groups, and no significant differences between pre- and postoperative hyponasality ratings were found for either group. The selection of the surgery was based on the preoperative ratings of perceived hypernasality and evaluation of velopharyngeal physiology. The authors concluded that severity of VPD is an essential factor when considering the management of VPD and recommended thorough preoperative assessment which is essential for treatment planning for VPD. Even though the authors used the retrospective study design, they included perceptual and instrumental method for comparison.

Elbarbary and Ghandour (2008) studied the treatment outcome of modified sphincter pharyngoplasty in individuals with VPD following palatal repair regardless of the pattern of closure. Forty three subjects were included in the study in the age range of 4 to 16 years. The speech assessments were carried out preoperatively and six to twelve weeks postoperatively prior to speech therapy. The auditory perceptual evaluation of speech was carried out on a 5 point rating scale to evaluate nasality, consonant precision, compensatory articulation, audible nasal air escape and overall intelligibility of speech. For nasopharyngeal videofibroscopic evaluation the velopharyngeal valve movement was recorded while the individual repeats the speech samples from the protocol of assessment of VPD. The movement of the each component was given a score of 0 to 4, where 0 is the resting position and 4 is the maximum movement position. The stimuli for nasometric evaluation consisted of nasal and oral sentences which were used according to the protocol for assessment of VPD. The results revealed statistically significant reduction in the degree of open nasality (96%), glottal articulation (45.5%) and pharyngalization (74.5%) following sphincter pharyngoplaty. The postoperative results of video nasoendoscopy revealed that velopharyngeal port achieved functional closure in the majority of subjects and was categorized as circular in thirty subjects and coronal in thirteen. The mean postoperative nasalance values for oral sentences reduced significantly to 21.1% from a pre-operative mean value of 44.3 %. A significant increase in the overall speech intelligibility (86% of individuals) was delineated regardless of pattern of velopharyngeal closure. The authors provided detailed description of articulatory errors before and after surgery. The sphincter pharyngoplasty demonstrated a satisfactory improvement in the velar function as it substitutes the entire velopharyngeal valve.

Van Lierde, Bonte, Baudonck, Cauwenberge and De Leenheer (2008) studied speech outcome on articulation, resonance, speech intelligiblity and voice characteristics in seven subjects in the age range from 4.7 to 9.1 years (mean age of 6.9 years) pre and postoperatively following pharyngeal flap surgery. The instrumental assessment procedures such as Nasometer I (Model 6200), Dysphonia severity Index (DSI) and the perceptual assessments were carried out in these subjects one week preoperative to pharyngeal flap and postoperatively for six weeks and one year. The stimuli used for articulation assessment was picture naming test which included line drawings of common objects and nouns. The responses were subjected to phonetic analysis. The results showed that all subjects were able to produce all vowels and consonants after one year follow up. In the phonetic analysis three types of errors were observed they are incorrect production of the trill sound /r/ (86%) included in the consonant clusters /schr/ (57%) or /gr/ (43%), the /s/ (57%) and the /sch/ (57%) sounds. The speech samples used for the perceptual assessment of speech intelligibility and resonance were five minute sample of connected speech on school and free time activities and reading of standardized nasometric sentences. The responses were audio and video recorded and was perceptually judged for speech intelligibility and nasality by two speech pathologists experienced assessing individuals with CLP. On five points nominal scale the results revealed statistically significant difference between pre-operative and two post-operative conditions in auditory perceptual ratings of speech intelligibility and nasality. The pre –operative nasality and speech intelligiblity was found to be deviating from normaly and post operatively these rating scores improve towards normality. The results also showed statistically significant difference between the nasalance values preoperatively and age specific normative data. The pre-operative nasalance values were higher than that of the normative values but one year post operatively after the pharyngeal surgery normal nasalance values were obtained for standard Flemish speech. The perceptual voice evaluations of these subjects were done one year postoperatively using GRBAS scale by two experienced voice therapists. The perceptual voice assessment revealed that all the subjects had a median of G0.5 R0.4 B0 A0 S0 and overall vocal quality in this population expressed as the DSI was 1.7 (range 0–4.8). The results showed that one year after pharyngeal flap surgery normal voice characteristics were seen. The incorrect production of the trill sound /r/ and the fricatives /s/ and /sch/ were observed. The authors concluded that slightly impaired speech intelligibility is determined by the presence of consistent articulation disorders in the post-operative analysis.

Wojcicki and Wojcjcka (2010) evaluated the treatment outcome of VPD after simultaneous double Z-plasty and sphincter pharyngoplasty in 14 children with a mean age of 14 years. The pre and post-operative speech of the children were recorded for comparison after the surgical intervention. The evaluations of perceptual speech assessments for hypernasality, hyponasality and speech intelligibility were done. The speech intelligibility, hypernasality and nasalance ratio were assessed when the subjects were asked to repeat a nonnasal text several times and the words produced were marked on a 5 point rating scale, where one represents fully intelligible speech and 5 unintelligible speech. The hypernasality was also evaluated on a five point scale where 1 as normal and 5 as severe. The nasometric recordings were performed for assessing the nasalance ratio and nasofibroscopy was done for assessing the length of the soft palate. The nasalance ratio was evaluated using objective automated testing of nasality. The velopharyngeal closure was evaluated on a 4 point rating scale [(1)100% = full closure, (2) 80-100%= slight insufficient closure, (3) 50-80% = Marked insufficiency, (4) <50% = extreme insufficiency. The outcome of the management was evaluated on four parameters such as closure, speech intelligibility, nasality and nasalance index. The follow up examination was done 6 months after surgery and for three individuals it was three months after surgery. Before the surgery 9 individuals had velopharyngeal closure below 50% and for 5 subjects it ranged from 50 to 80 %. After surgery 4 individuals had 80-100% closure and 10 subjects had complete closure. In the pre-operative condition, the results showed that speech intelligibility was poor in 10 subjects, 2 had unintelligible speech and 2 with limited intelligibility. After treatment speech was reported to be fully intelligible in 4 subjects, partially intelligible in 9 subjects and one individual had limited intelligibility. All the subjects had abnormal nasalance about mean value of 44% in the pre-operative condition and after surgery it was between 26 to 30%. Complete recovery was seen in 10 subjects (71%), and the other individuals had an improved recovery (29%). The authors concluded that the speech characteristics improved significantly after concurrent z plasty and sphincter pharyngoplasty.

Sullivan, Vasudevan, Marrinan and Mulliken (2011) compared the speech outcomes of 58 individuals with symptomatic submucous cleft palate who underwent three different procedures for VPD. The subjects underwent one of the three procedures such as two-flap palatoplasty with muscle retro positioning, furlow double opposing z plasty or pharyngeal flap. The subjects were retrospectively selected from 1984 to 2008. The perceptual speech assessment includes Pittsburgh weighted values for speech symptoms associated with velopharyngeal incompetence ratings (Mc Williams & Philips, 1979). The perceptual assessment variables include resonance, intraoral pressure and nasal emission. The overall velopharyngeal competence was evaluated using a four point rating scale (1= normal; 4= insufficient competence). The results showed that the three procedures differ significantly depending on the age of repair. The two flap palatoplasty (n=24) and Furlows double opposing Z plasty (n=19) were performed in children of younger median age of 2.4 and 3.9 yrs. However, pharyngeal flap procedure (n=15) was performed in children with a mean age of 9.5 years. The results also showed that the success percentage or normal velopharyngeal competence was achieved in 30% of two-flap palatoplasty, 67 % of furlows double opposing z plasty and 92% of individuals who underwent pharyngeal flap procedure. The authors concluded that furlows double opposing z plasty and pharyngeal flap is more effective than two stage palatoplasty.

Paniagua, Signorini, da Costa, Collares and Dornelles (2013) studied the key procedures used to assess velopharyngeal function in individuals with cleft lip and palate and to decide whether there is a relationship between and listener's perceptual judgement and videonasoendoscopy results. The authors piloted an organized review of the literature on auditory-perceptual and instrumental evaluations by examining the databases such as the Cochrane, PubMed, Medline, Lilacs, and SciELO databases from October 1990 to November 2012. They found 1,300 studies on the area of interest published from 1990 to 2012. Of these, 56 studies were detailed on velopharyngeal physiology; 29 studies offered data on velopharyngeal physiology using at least 1 instrumental assessment and/or 1 auditory-perceptual assessment, and 12 studies associated the results of both types of assessments. Only 3 studies described in detail the analysis of both methods of assessing velopharyngeal function; however, relations between these findings were not analyzed. They concluded that few studies indicated that both the detailed criteria for analyzing the results of the assessment procedure and the relationship between videonasoendoscopy results and auditory-perceptual assessments.

The above review highlighted the need for documenting the pre and post-operative condition using perceptual and instrumental method. The objectives of the most of the articles reviewed above were to compare the different surgical treatments that are utilized by craniofacial teams for the management of individuals with VPD. The methods of reporting speech outcomes are variable and inconsistent and there is no standard assessment protocol measuring the speech outcome. These studies do not compare the different perceptual scales and instrumental measures that were done to evaluate the sucess of the different surgical procedures. In depth statistical analysis was not done and most of the studies compare the mean percentage scores of the rating done by the listeners across the pre and post-operative conditions.

Need for the study

The incidence of CLP is one in 500 live births in India (Ankola, Nagesh, Hegde & Karibasappa, 2005). Most of the surgeries for cleft palate aim at correcting the structural and functional problems. Inspite of early correction of the structure of the palate, most of the individuals have problems in velopharyngeal closure due to scar on the palate, lack of tissue which leads to poor movement of velum. As the incidence of VPD is more, it calls for the attention of speech language pathologists for studying the assessment and outcome of rehabilitation methods. A detailed correlation of perceptual and instrumental assessment before and after surgical repair of VPD also needs to be studied in Indian context. Inspite of published western studies available in the literature, the same cannot be generalized to an Indian context due to the difference in the language spoken as the place of articulation (Upadhyaya, 1972) and acoustic characteristics of phonemes in Kannada[1] language differ from that of other western languages. The review of literature also suggests currently, there are no published studies which directly investigate the ability to assess articulation and resonance in Kannada speaking individuals with VPD. The speech parameters were only analysed subjectively in most of the studies. So, there is a need for appropriate speech and resonance evaluation involving perceptual and instrumental components in Kannada language. Therefore, the current research is aimed to study the effect of surgery on speech parameters pre and post operatively following VPD surgery.

[1] Kannada has several dialects, they are known as the Dharwar or North Karnataka dialect, the Karwar dialect, the Mysore dialect and so on. The basic Kannada vowel system consists of five long and five short vowel phonemes. Kannada has a native Dravidian inventory of consonants, with a superimposed system of aspirated consonants and supplementary sibilants borrowed from Indo-Aryan, and with /f/ and /z/ borrowed from Urdu and reinforced by English loans. In Kannada, consonants do not occur in final positions (Schiffman.H, 1979). The pressure consonants in Kannada language acoustically differ from western languages on VOT, F1 cutback and temporal extension of formant transitions (Savithri, Pushpavathi & Sujatha, 2007).

Aim

The aim of the current study was to investigate the effect of different types of surgery on speech characteristics in individuals with velopharyngeal dysfunction at each of the two follow-ups i.e 3 months and 6 months post surgery.

Objectives

The objectives of the current research was to study the

- Effect of different types of surgery on articulatory characteristics of individuals with VPD across conditions.
- Effect of different types of surgery on resonance characteristics of individuals with VPD across conditions.
- Effect of different types of surgery on speech understandability and intelligiblity of individuals with VPD across conditions.
- Effect of different types of surgery on Dysphonia severity index (DSI) in individuals with VPD across conditions.
- To investigate the correlation between perceptual and instrumental assessment of resonance in individuals with VPD before and after secondary surgery.

Hypothesis to be verified

The following null hypotheses have been formulated for verification in the present study.

- It is hypothesized that there would be no effect of surgery on articulatory characteristics of individuals with VPD across conditions.
- It is hypothesized that there would be no effect of surgery on resonance characteristics of individuals with VPD across conditions.
- It is hypothesized that there would be no effect of surgery on speech understandability of individuals with VPD across conditions.
- It is hypothesized that there would be no effect of surgery on DSI of individuals with VPD across conditions.
- It is hypothesized that there would be no correlation between perceptual and instrumental assessment of resonance in individuals with VPD before and after secondary surgery.

CHAPTER III

METHOD

3.1 Participants

The participants of the study were selected from the smile train database of Vikram Hospital, Mysuru. The database revealed that 150 individuals had undergone primary palatal repair (cleft of hard palate and soft palate, cleft of the soft palate, submucous cleft palate) for the closure of the cleft from 2005 to 2008. Out of 150 individuals from the database, only 100 of them could be contacted through post cards and phone calls. Of the 100 individuals, 60 individuals responded and they were further evaluated by the craniofacial team at unit for structural oro-facial anomalies (U-SOFA), All India Institute of Speech and Hearing, Mysuru for the presence of VPD. The craniofacial team include plastic surgeon, speech language pathologist, orthodontist, prosthodontist and a psychologist.

Out of the sixty participants, 30 individuals in the age range of 7 to 25 years (Mean age =14.2 years) fulfilling the following inclusion and exclusion criteria were considered for the study for a baseline (presurgical stage) evaluation.

Inclusion criteria

- Individuals diagnosed to have moderate/severe VPD with repaired cleft lip and palate/ cleft palate/submucous cleft palate by craniofacial team using direct visualization procedures such as Cineradiography.
- Individuals with Kannada as their native language.
- Individuals who have attended speech therapy sessions of less than two weeks after primary palatal repair.
- Individuals with hearing threshold less than 20 dB in the poorer ear were considered based on the hearing evaluation.
- All the participants were matched for socio economic status by using readapted version of National Institute of Mental Health (NIMH) Socioeconomic Status Scale, (Venkatesan, 2009).

- A WHO – ten questions disability screening checklist (Singhi, Kumar, Malhi, & Kumar, 2007) was administered on participants for screening any associated disabilities.

Exclusion criteria

- Individuals with isolated cleft of the lip or cleft of hard palate or cleft lip with hard palate.
- Individuals with evidence of severe dyspraxia/dysarthria were not included. Frenchay dysarthria assessment (Enderby, 1983) was used to exclude individuals with dysarthria.
- Individuals with cognitive impairment were excluded based on the results obtained by age appropriate intelligence tests done by psychologist.
- Individuals having congenital defects such as heart and pulmonary defects (based on the reports by paediatrician and general physician) were excluded.
- Individuals with syndromic conditions such as velocardiofacial syndrome were excluded from the study.
- Individuals with large tonsils, adenoid, palatal fistula and nasal pathologies such as allergic rhinitis, nasal polyps were excluded based on the evaluation reports by ENT specialists.

The thirty subjects considered for the study were further grouped into children (12 Males, 10 Females) in the age range of 7-12 years and young adults in the age range of 18 to 25 years (5 Males and 3 Females). Based on surgical intervention the participants were further divided into three groups [Group I - Palatoplasty (18), Group II - Pharyngoplasty (8) and Group III - combined surgery (4)]. The demographic details of the participants are depicted in Table 1.

Table 1.

Demographic Details of Individuals with Velopharyngeal Dysfunction

S.No	Age (yrs)	Gender	Children /Adult	Provisional Diagnosis	Date of surgery	Type of VP surgery	Category of Surgery
1	12	M	C	RCLP	07.06.2012	FDOZ	
2	8	F	C	RCLP	10.07.2012	FDOZ	
3	11	M	C	RCLP	17.10.2012	FDOZ	
4	8	F	C	RCLP	15.10.2012	FDOZ	
5	11	M	C	RCLP	10.03.2014	FDOZ	
6	18	M	A	RCLP	17.04.2012	FDOZ	**Group I**
7	7	F	C	RCLP	28.08.2012	FDOZ	Palatoplasty
8	12	M	C	RCP	21.08.2012	FDOZ	(n=18)
9	7	F	C	RCP	01.08.2012	FDOZ	
10	10	M	C	RCP	25.09.2012	FDOZ	
11	12	M	C	SMCP	10.09.2012	FDOZ	
12	9	F	C	SMCP	14.04.2012	FDOZ	
13	7	M	C	SMCP	24.04.2012	FDOZ	
14	7	M	C	SMCP	17.10.2012	FDOZ	
15	9	M	C	SMCP	11.04.2012	FDOZ	
16	7	F	C	SMCP	20.09.2011	FDOZ	
17	7	M	C	SMCP	01.10.2012	FDOZ	
18	9	M	C	SMCP	07.06.2012	FDOZ	
19	19	M	A	RCLP	12.10.2012	HP	
20	18	M	A	RCLP	15.11.2012	HP	**Group II**
21	7	F	C	RCP	10.01.2013	HP	Pharyngoplasty
22	20	F	A	RCLP	15.02.2013	HP	(n=8)
23	25	M	A	RCLP	31.10.2012	SPF	
24	22	F	A	RCLP	16.02.2012	SPF	
25	10	M	C	RCP	05.06.2012	SPF	
26	12	F	C	RCP	10.06.2012	SPF	
27	12	F	C	RCLP	10.02.2013	FDOZ & SPF	**Group III**
28	12	F	C	RCLP	15.04.2013	FDOZ & SPF	Combined
29	18	M	A	RCLP	21.05.2013	FDOZ & SPF	surgery (n=4)
30	18	F	A	SMCP	09.05.2013	FDOZ & SPF	
N=30	14.2 (Mn)	M=17 F=13	C =22 A= 08	SMCP =9; RCLP =15 RCP =6			

Note.[RCLP –Repaired cleft of lip and palate, RCP –Repaired cleft of soft palate, SMCP –submucous cleft palate, FDOZ- Furlow's Double Opposing Z plasty, HP-Hyne's Pharyngoplasty, PF-Superior based Pharyngeal Flap, M –Male , F- Female, C-Children, A-Adult, Mn- Mean Age]

3.3 Ethical Consideration

This study was conducted with the clearance from AIISH Bio behavioural ethics committee. The written consent was obtained from the caregivers / parents of the children with VPD and from the adult participants, self-consent were obtained. Participants / Caregivers were provided information in Kannada language (Appendix D) about the aim, objectives, method of the research and approximate duration of testing.

3.4 Procedure

Thirty individuals who were diagnosed by the craniofacial team as having VPD were considered for the study. These subjects underwent secondary VPD surgery and based on the type of surgical intervention they were divided into three groups. The group I consisted of 18 subjects who underwent palatoplasty surgery, group II consisted of 8 subjects who underwent pharyngoplasty surgery and the group III consisted of 4 subjects who underwent combined palatoplasty and pharyngoplasty surgery. The perceptual and instrumental assessments were carried out for subjects with VPD before and after surgery. The different parameters considered for assessment of speech in individuals with VPD are articulation, resonance, speech understandability and voice. The stimuli considered for the present study were meaningful Kannada words loaded with pressure consonants, sentences (oral and nasal), and spontaneous speech in Kannada language. The stimuli used were audio recorded using Olympus WS-550 M digital voice recorder with the help of a native Kannada speaker. The native Kannada speaker was a 25 yrs male with normal articulation and voice quality. The audio recorded stimuli were presented to the subjects through headphones and the subjects were asked to repeat the stimulus presented through the headphones.

The perceptual and instrumental assessments were carried out for individuals with VPD across three conditions. In the condition I, the assessments were carried out one week prior to the surgical management, in the condition II the evaluations were carried out 3 months postoperatively and 6 months post-operative follow ups were carried out in the IIIrd condition. All the participants were followed up in the second condition (after 3 months) following surgical intervention. For the third condition (6 months follow up), only 15 participants [palatoplasty (10), pharyngoplasty (4) and combined surgery (1)] could be contacted and they underwent minimum of 15 sessions of speech therapy for management of articulation and resonance disorders. The speech therapy sessions were approximately three sessions per week during the 3-6 months period. The speech therapy goals were oriented on improving auditory discrimination, improving articulation by teaching appropriate place of articulation, enhancing resonance by providing audio visual feedback. After IInd post-operative follow up, the individuals underwent speech therapy at different time intervals. Hence, all these individuals were called for followup after six months. The audio-video recording was done after six months followed by cineradiographic evaluation. The Cineradiographic evaluation of velopharyngeal closure of isolated vowels (/a/, /i. and /u/) was carried out for all the subjects' pre operatively. The post-operative recordings of cineradiographic evaluation was carried out only for the subjects of 6 months followup (condition III) because to avoid the frequent exposure to x-rays.

3.4.1 Materials

The study was aimed to investigate the changes across speech parameters in different conditions. Hence the stimuli considered for assessing the speech parameters was different for each task.

3.4.1.1 Words with pressure consonants.

One of the objectives of the study was to assess the articulation across conditions. The high pressure consonants in Kannada language were considered for the assessment of articulation in individuals with VPD. Based on these consonants, list of 56 meaningful words in Kannada language were selected from the text books of IInd grade and other resources. The word list consisted of 14 pressure consonants of Kannada language in both initial and medial position (Appendix A). The words selected were simple and meaningful. This word list was subjected to content validity by giving the material to three speech language pathologists trained in assessing resonance disorders. The judges were asked to check for the context and position of the pressure consonants in the words. The content validity of the world list was rated using a Likert type ordinal four point rating scale (1 = not relevant, 2 = somewhat relevant, 3= quite relevant, and 4= very relevant). The rating of 1 and 2 are considered as content invalid, whereas rating of 3 and 4 are considered as content valid. Totally 28 words were selected from the list of 56 words by administering this rating scale for content validity. The words were selected in such a way that each pressure consonants would occur once in initial and medial position.

The list of words prepared were audio recorded using a digital voice recorder (Olympus WS-550M) with the help of a native male Kannada speaker with an inter stimulus interval of 3 seconds in a quiet room. The recorded word list was given to 5 native Kannada (normal) speaking SLP’s for perceptual analysis to confirm that all the words were articulated correctly. The recorded word list formed the stimuli for assessment of articulation. The participants repeated these words.

3.4.1.2 Sentences

Five standardized oral and nasal sentences (Appendix A) in Kannada language were considered from a study by Jayakumar and Pushpavathi (2005). The audio recording of these Kannada sentences was carried out by a native Kannada speaker with an inter stimulus interval of 5 seconds between each sentences in a quiet room. The recorded sentences were given to 5 native Kannada speaking speech language pathologists for perceptual analysis to confirm that all the words in the sentences were articulated correctly. The audio recorded oral and nasal sentences were considered as stimuli for perceptual and instrumental assessment of resonance and perceptual assessment of speech understandability in individuals with VPD. The participants repeated these sentences.

3.4.1.3 Spontaneous speech

The participants were asked to say a monologue about their school / leisure activities or hobbies in Kannada for a minimum duration of about three minutes (approximately 150 to 200 words). The spontaneous speech sample was elicited and the audio - video recordings of spontaneous speech sample was obtained from individuals with VPD in a quiet room condition. The audio-video recordings of the spontaneous speech samples were considered for the perceptual assessment of resonance and speech understandability.

The speech samples i.e words, sentences and spontaneous speech were audio video recorded using Sony DCR-SR88 Handy cam recorder and the recorded samples were randomized across three conditions and presented to three trained SLP’s for perceptual judgement. The mean percentage of perceptual ratings were calculated by averaging the ratings of trained judges divided by the total number of judges and this mean percentage was considered for further analysis.

Judges and Listening Training Sessions

Three speech language pathologists (SLP's) were considered as judges for the auditory perceptual judgement of articulation, resonance and speech understandability. The judges were in the age range of 28 to 30 years who were involved in clinical and research activity in Unit for structural orofacial anomalies. Among three SLP's considered, investigator also served as one of the judge. The other two judges were trained by the investigator for perceptually judging the speech samples of individuals with VPD. They were considered for judging all the speech parameters across the conditions. The five speech samples were considered for the training sessions which had evident hypernasality, nasal air emission, voice problems and articulation errors. The speech samples considered for training sessions were audio-video recordings of words, sentences, and spontaneous speech samples. These samples were randomized and presented to the judges. The listening training sessions for the judges were carried out for the duration of 1hour per day for five days. The training sessions included orientation on VPD using a power point slides describing about its nature, types, causes, various assessment procedures and different terminologies with their definitions. They were also showed the normal lateral images of the velopharyngeal closure. After understanding the normal images, they were shown the images of inadequate velopharyngeal closure.

During training, the judges were provided with glossary of terminologies (Appendix B) and descriptors for perceptual analysis that would be included for analysis of these parameters. The judges were also made to identify each of the parameter and once they were able to identify they were requested to rate the same. A four point rating scale (0-3) was used for perceptual rating of nasality and speech understandability. The mean perceptual rating scores of all judges for each speech parameter were calculated for each trial. The calculated mean scores were given back to the judges as feedback to correct their errors. The samples included for perceptual training were not considered for the main study.

All the audio and video recordings of the speech samples in the study were perceptually judged by the same SLP's who were considered for the training sessions.

The perceptual assessment was performed by the same judges using a four point ratings scale (0-3) proposed by Henningsson et al. (2008) which assess the parameters such as articulation, resonance and speech understandability (Appendix C) for reporting speech outcomes in individuals with VPD.

3.4.3 Perceptual Evaluation of Speech Characteristics

3.4.3.1 Articulation

A list of audio recorded 28 meaningful Kannada words containing the 14 high pressure consonants in word initial and medial position were considered for the assessment of articulation. The Kannada word list selected was presented to individuals with VPD through headphones in a quiet room situation. The participants were asked to repeat the words that they would hear through the headphones during the inter stimulus interval of three seconds which was predefined after each word. The participant's responses were obtained across three conditions [condition I (pre-operative) condition II (3 months follow up), and condition III (6 months follow up)] and they were audio-video recorded. The recorded speech samples of all the participants were randomized across conditions and presented to the judges for articulatory assessment.

The participant's responses were transcribed phonetically using International Phonetic Alphabet (IPA) transcription by the judges. The speech samples were analyzed for articulatory errors by using three different methods. At first, the articulation parameters were perceptually rated according to a binary decision of "0" within normal limits / no articulation errors or "1" presence of articulatory errors. The mean percentage of overall articulatory errors were obtained by calculating the number of errors in the target word and divided by the total number of words. The second type of articulatory error analysis includes traditional error analysis such as substitutions, omissions, distortions and addition (SODA). The mean percentage of SODA errors were obtained from the judges by calculating the number of errors in each type (SODA) divided by the total number of target words. The third type of articulatory error analysis includes cleft type characteristics and these were analyzed according to the universal parameters rating for reporting the speech outcome in cleft palate (Henningsson et al., 2008). The cleft type characteristics were classified under three categories atypical backing of oral sounds to postuvular place, abnormal backing of oral sounds but place of articulation remains oral and errors due to nasalization. The atypical backing of oral sounds includes glottal and pharyngeal production of stops and fricatives. The abnormal backing of oral sounds include the velar and mid dorsum palatal production of stops and fricatives. The third and the last category of compensatory articulation was errors due to nasalization which included nasal fricative, substitution of nasal consonants for oral pressure consonants, nasalized voiced pressure consonants and weak oral sound production. The mean percentage of errors due to nasalization was calculated from the judges by obtaining the total no of errors in each category (eg. Glottal stops) divided by the total number of words with that target pressure consonanat (eg. Stop consonants).

3.4.3.2 Resonance

The perceptual evaluation of resonance characteristics such as hypernasality, hyponasality and nasal air emission of the individuals with VPD were assessed using spontaneous speech sample and repetition of audio recorded sentences (nasal and oral).

3.4.3.2.1 Hypernasality

The spontaneous speech and oral sentences were considered for perceptual judgment of hypernasality. A three minute spontaneous speech sample about the school and leisure activities in Kannada language was audio and video recorded. The participants were asked to repeat audio recorded oral sentences in Kannada which was presented through headphones. The speech samples were presented in a randomized order across speakers and oral/nasal conditions. The speech samples obtained were perceptually judged by trained speech language pathologists for hypernasality based on four point rating scale (0-3) (0 = Normal – acceptable, 1 = Mild - unacceptable distortion evident on high vowels, 2= Moderate- evident on high and low vowels, 3 = Severe- obvious on all vowels and consonants).

3.4.3.2.2 Hyponasality

The spontaneous speech sample and nasal sentences in Kannada language were considered for perceptual judgement of hyponasality. A three minutes sample of spontaneous speech about the school and leisure activities in Kannada language was audio and video recorded. The participants were asked to repeat audio recorded nasal sentences in Kannada which was presented through headphones. These samples were perceptually evaluated by the same three speech language pathologists trained in judging the resonance disorders. The speech samples were presented in a randomized order across speakers and conditions. A four point rating scale (0-3) was used for perceptual judgement of hyponasality (0= Acceptable, 1= Mild – evident but unacceptable hyponasality, 2= Moderate- all vowels reduced nasality and 3= Severe- evident denasal production of all vowels and nasal consonants).

3.4.3.2.3 Nasal air emission

The audio-video recordings of spontaneous speech sample and oral sentences considered for the perceptual judgement of hypernasality were also considered for assessing nasal air emission. The speech samples obtained were presented in a randomized order across speakers and conditions. It was rated on binary categories such as present/absent. If the judges rated present, then they were further asked to rate the degree of nasal air emission on a four point rating scale (0-3) (0= Acceptable/Normal, 1= Mild, 2 = Moderate, 3= Severe). The phoneme specific nasal air emission was recorded separately.

3.4.4 Speech Understandability

The spontaneous speech and sentences were considered as sample for the assessment of hypernasality, hyponasality and speech understandability. The participant's responses were audio-video recorded for further analysis. The speech samples obtained were randomly presented to three judges (SLP's) for perceptual judgement. A four point rating scale (0-3) was used to judge the speech understandability [(0) = within normal limits – speech is constantly easy to understand, (1) Mild = speech is sometimes difficult to understand, (2) Moderate = speech is often difficult to understand, (3) Severe = speech is difficult to understand most of the time (Henningsson et al., 2008). The mean percentage of the perceptual ratings for speech understandability was calculated by averaging the perceptual rating scores obtained from three trained judges.

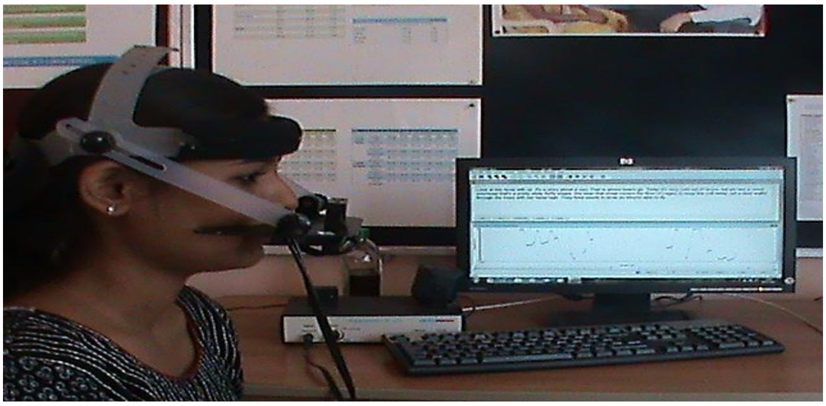
Speech Intelligiblity was also calculated by using the percentage of intelligible words (PIW) in the speech sample. It is the ratio of number of words understood by the listener to the total number of words in the speech sample transcribed by the listeners (Gordon-Brannan & Hodson, 2000; Shriberg, & Kwiatkowski, 1985). The mean percentage of intelligible words was calculated across conditions.

3.4.5 Instrumental Evaluation of Speech Characteristics

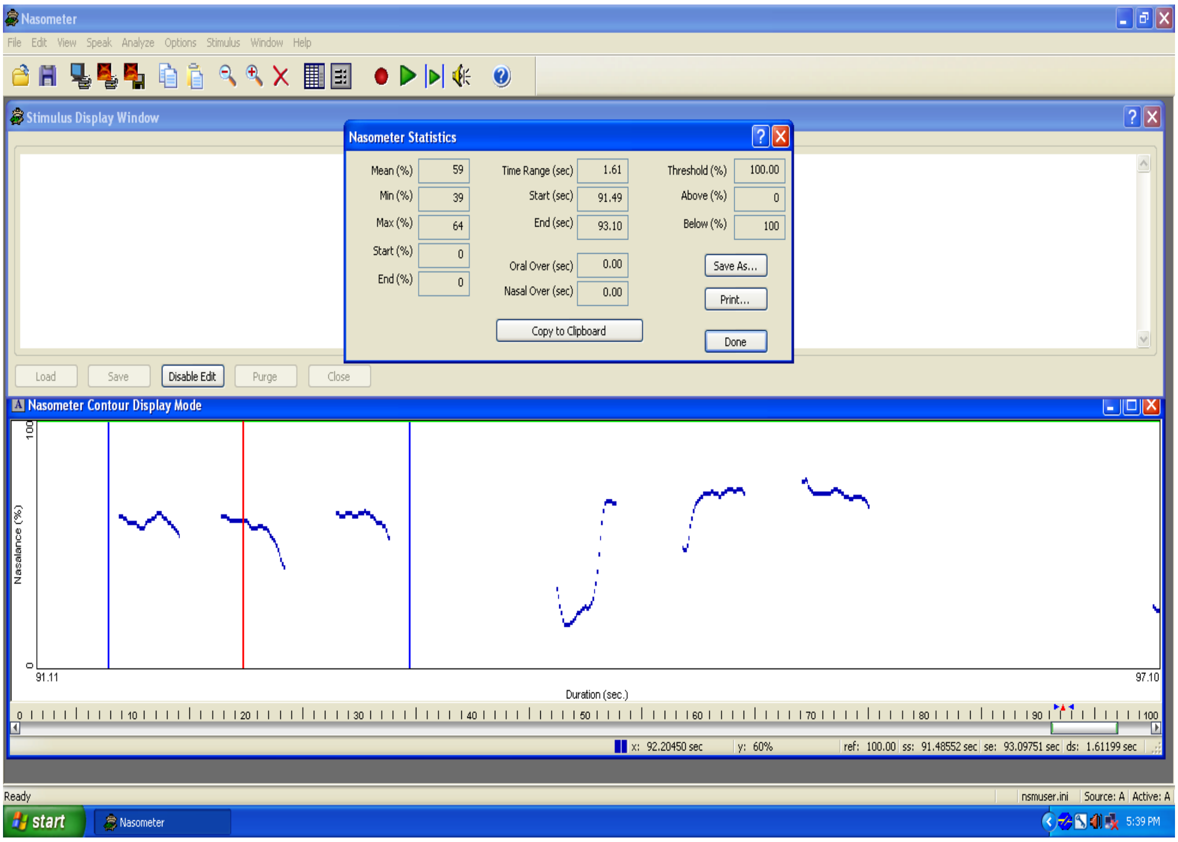
3.4.5.1 Resonance

3.4.5.1.1 Nasometric evaluation

Nasometer II (Model 6450) a microcomputer based system manufactured by Kay Elemetrics (2003) was used for the instrumental evaluation of the resonance characteristics of individuals with VPD. The stimuli included repetitions of isolated vowels (/a/, /i/ and /u/), CV syllables which includes voiced (/b/, /d/ and /g/) and unvoiced (/p/, /t/, and /k/) consonants with different vowel combinations (/a/, /i/ and /u/), standardized audio recorded five oral sentences and five nasal sentences (Jayakumar & Pushpavathi, 2005). The Nasometer was setup in a suitable quiet room situation. It has a headset, comprising a sound divider with microphones on either side, sensing the oral and nasal acoustic energy of the participant's speech. The instrument was calibrated prior to the recording as per the specifications provided by the manufacturer. The participants were seated comfortably and the Nasometer headset was placed on the subject's head and secured using the top adjustment band and the Velcro strip in the back (Fig.1a). Then the participants were instructed to repeat the stimulus after the audio recorded stimuli by a native speaker played through the speakers in a quiet room situation. After the recording of each stimulus a two second interval was given so that the instrument acquires the each stimulus with a separation.



(a) Nasometer II (6450) with head set placed on individual with VPD.



(b) Nasogram display for vowels /a/ and /i/ in VPD

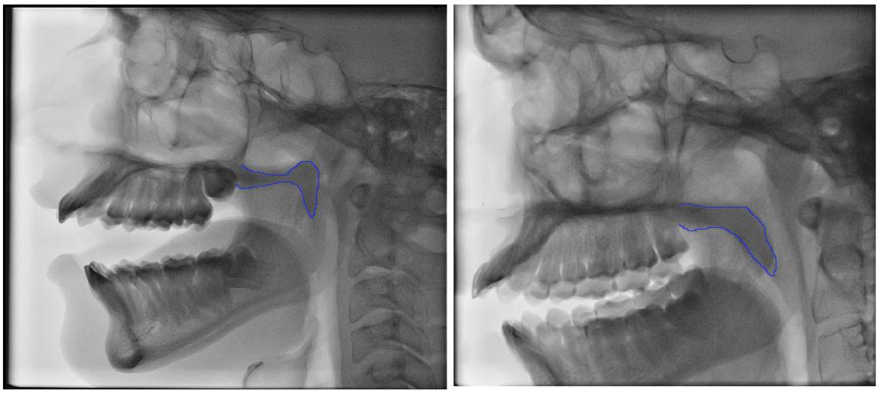
Figure 1. (a) Nasometer II 6450 Instrumentation and (b) Nasogram of vowels /a/ and /i/ in individuals with VPD.

The Nasalance trace was monitored throughout the recording for ensuring the correct data acquisition (Fig.1b). The extraneous events such as spontaneous cough or the incorrect repeated production of the syllables was noted and those incorrect responses were deleted from the list. After completion of each sample the recording was saved in the computer and subjected to analysis. The speech samples collected were analyzed for mean, minimum and maximum nasalance values for each sample.

3.4.5.1.2 Cineradiographic evaluation

Cineradiographic evaluation was done to assess the velopharyngeal closure based on lateral view across the condition. In cineradiography procedure, the participants were positioned between the fluoroscope and the image intensifier. They were seated comfortably in a normal upright position with the head held stable with the help of a head rest to obtain the x-ray image. The image was amplified by the electronic intensification, making it bright enough to be recorded in the video camera.

Before starting this procedure a suspension of colloidal barium sulfate, a radiopaque substance was instilled in the nasopharynx for better visualization of the contrast. The speech tasks considered were repetition of isolated vowels (/a/, /i/, /u/) three times each and lateral view was recorded for clear observation of velar movements. The audio recording of the vowels was done simultaneously during the procedure. The video samples which were embedded with the audio samples were judged by three speech language pathologists. The video samples were randomly presented to the judges across pre and postoperative conditions.



(a) (b)

*Figure 2.*Cineradiographic images of velopharyngeal closure for vowel /a/ [(a)- Normal closure, (b) – inadequate closure]

Figure 2 shows the lateral cineradiographic images of normal closure and inadequate closure during the production of isolated vowel /a/. The same trained judges were asked to view the video samples clearly and judge the samples for velopharyngeal closure using a rating scale. The severity of the velopharyngeal closure dysfunction was established based on the guidelines given by international working group (Golding-Kushner et al, 1990). A five point rating scale (0-4) was used to rate the velopharyngeal dysfunction (0 = Normal - where the subject consistently achieves adequate closure, 1= Mild- where the subject does not consistently achieve appropriate closure, 2 = Moderate - where the subject closure is not consistently appropriate, 3= severe, where the subject closure is mostly inappropriate, 4= Very severe, where the subject does not achieve any closure). The cineradiographic procedure was carried out in a cathlab at a hospital setup with the help of radiologist and Plastic surgeon. The mean perceptual ratings of judges for velopharyngeal dysfunction were calculated by averaging the ratings of the trained judges

3.4.5.2 Voice

3.4.5.2.1 Dysphonia severity index (DSI)

The assessment of voice was done by investigating Dysphonia Severity Index (DSI) across three conditions. For calculating the DSI value, maximum phonation time (MPT in seconds), highest frequency (Fo-high in Hz), lowest intensity (I-low in dB), and jitter (%) are required. Lingwaves voice clinic suite pro software Version 2.5 (Wevosys, Germany) was used for calculation of DSI .The Lingwaves software is a computer based standardized measurement system for voice and speech diagnostics. To obtain maximum phonation time, participants were instructed to sit in a comfortable posture and take a deep breath. After taking a deep breath they were asked to sustain the vowel /a/as long as they could at habitual pitch and comfortable loudness to a microphone connected to the software. The procedure was modelled by the investigator and the participant was visually encouraged during his turn of vowel prolongation. The duration of the sustained vowel was measured using Adobe audition software (version 3). The best and longest sustained vowel /a/ of the three trails was measured is seconds (s) and considered for analysis.

Voice diagnostic centre (VDC) of Lingwave software was used to measure the highest frequency and the lowest intensity parameters of DSI. The voice diagnostic centre represents a combined voice range profile analysis and voice quality analysis. The recordings of Fo-high and I-low were taken with the instrument in VDC mode and with a table mounted sound level meter kept at a constant distance of 30 cm from the mouth. For obtaining highest frequency, the participant was instructed to glide the vowel /a/. The participant was further instructed and encouraged to use the visual feedback from the display on the computer screen to produce the best possible highest frequency. Initially two trials were obtained followed by three test recordings and the best of the three highest frequencies on the test recordings was considered for further analysis. For obtaining lowest intensity (I-low), the participant was instructed to produce the vowel /a/ as soft as possible. Three test recordings were obtained followed by two trials and the lowest of the three lowest intensities on test recordings were considered for further analysis. The highest Fo and lowest intensity were calculated from phonetogram VDC display.

The Jitter (%) was determined with the aid of Vospector –DSI in Lingwaves software. The participants were instructed to sit in a comfortable posture and sustain the vowel /a/ at habitual pitch and loudness to a table mounted sound level meter kept at a constant distance of 30 cm from participant's mouth and connected to Lingwaves software. The recording was done at 44 kHz sampling rate in the window length of 5 seconds. A midvowel segment of 3 seconds duration was selected for analysis by avoiding the initial and final 1 second segments.

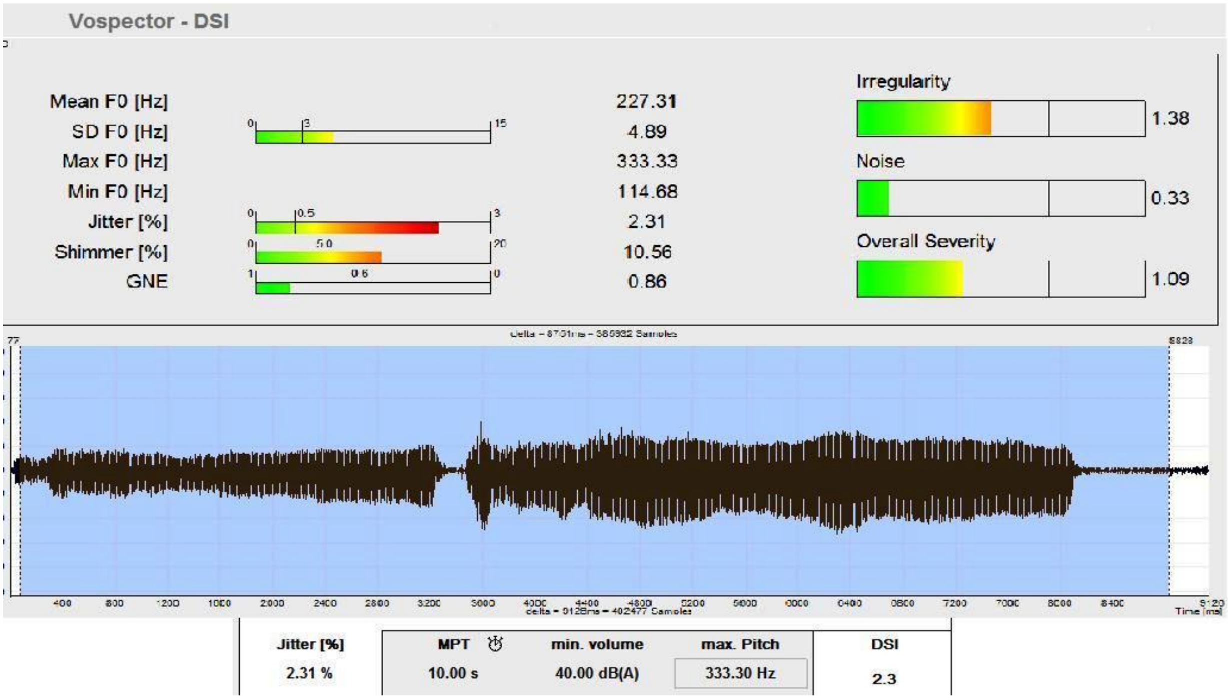


Figure 3.Vospector - DSI software of an individual with VPD

The jitter (%) obtained on analysis was used for further calculations. With the obtained values, the DSI was calculated using an equation (DSI = 0.13x MPT(s) + 0.0053 x Fo-high (Hz) – 0.26 x I-low (dB) – 1.18 x jitter (%) + 12.4) that was already loaded in the Lingwave software. The same procedure was used after three and six months postoperatively. The obtained results were compared across conditions.

Statistical Analysis

The analysed data for the participants were compiled across three conditions [Condition I – preoperatively (n=30), Condition II – 3 months follow up (n=30) and Condition III - six months follow up (n=15)] and further divided into three groups based on the surgical management [Group I – Palatoplasty (n=18), Group II – Pharyngoplasty (n=8) and Group III -Combined surgery (n=4)] for all the speech parameters. The quantitative and qualitative data obtained were subjected to statistical analysis using Statistical Package for Social Sciences (SPSS) version 21.

The quantitative data was obtained from speech parameters such as articulation, resonance (nasalance values), percentage of speech Intelligiblity and DSI values. The statistical analysis carried out were

- The Mean, Standard deviation and Median was calculated for all the quantitative data obtained from speech parameters.
- Shapiro-Wilks test of normality was done for quantitative data obtained from the speech parameters to find whether the data followed a normal distribution or not. In the normality test, group I followed normal distribution for all the quantitative data except compensatory articulatory errors.
- Kruskal Wallis test was carried out to find significant difference across groups for condition I and II.
- Mann-Whitney test was carried out to find significant difference across group I and II in condition III (As condition III of group III had only one subject).
- Repeated measures ANOVA was carried out to find significant difference across conditions in group I. This was followed by Bonferroni's multiple comparisons.
- Wilcoxon's signed rank test was done to find significant difference across conditions for Group II and III (Friedman's test could not be administered since few subjects were not present in all the conditions).

The qualitative data was obtained from the speech parameters such as perceptual rating of resonance, velopharyngeal and speech understandability. The statistical analysis carried out were

- The median and interquartile ranges (IQR) were calculated for the qualitative data obtained from three trained judges for speech parameters.
- The Croanbach's alphas (α) inter and intra-rater reliability analysis was performed for the 25% of the samples considered for the perceptual judgement.
- Kruskal Wallis test was carried out to find significant difference across groups for condition I and II.
- Mann-Whitney test was carried out to find significant difference across groups I and II for condition III. Kruskal Wallis could not be carried out for condition III because; Condition III of group III had one subject.
- Wilcoxon's signed rank test was carried out to find significant difference across conditions for all the groups (Friedman's test could not be administered since few subjects were not present in all the conditions).
- Spearman's rank correlation co-efficient (rho) was calculated to study the relationship between nasalance values and perceptual rating of resonance and ratings for velopharyngeal closure.

CHAPTER IV

RESULTS AND DISCUSSION

The aim of the present study was to study the effect of surgery on speech characteristics of individuals with VPD across conditions. The data was obtained from all the 30 individuals (17 males and 13 females) with VPD for each of the conditions I (pre surgery) and II (three months follow up) and for 15 individuals in Condition III (six months follow up). The subjects were further categorized into three groups based on the types of surgery that was performed on them. Out of 30 participants with VPD, 18 had undergone palatoplasty (Group I - Furlow's z plasty), 8 were performed with pharyngoplasty (Group II- Sphicter pharyngoplasty/ pharyngeal flap) and 4 underwent combined surgery (Group III- both palatoplasty and pharyngoplasty as a single procedure).

The quantitative data obtained from thirty individuals with VPD were subjected to Shapiro- Wilk's test of normality test to check whether the obtained data follow a normal distribution. The Shapiro-Wilk's statistic is based on the largest vertical difference between the theoretical and the empirical cumulative distribution function (Field, 2013). In this test two hypotheses, H_0 (null hypothesis) the underlying distribution is a normal distribution and H_1 (alternate hypothesis) the underlying distribution is not a normal distribution were tested. If the test is statistically significant (e.g., $p<0.05$), then data do not follow a normal distribution, and a nonparametric test has to be done. The results of Shapiro- Wilk's test showed that for percentage of overall articulation errors, SOD errors, nasalance values of (vowels, unvoiced and voiced consonants, sentences), percentage of speech intelligiblity, DSI and its parameters across condition for Group I (Palatoplasty) showed normal distribution ($p > 0.05$), thus accepting the null hypothesis. The compensatory articulatory errors of group I across conditions were the only parameter which did not show normality. For group II and III the results showed that the data did not follow normal distribution ($p<0.05$), thus rejecting the null hypothesis. The other variables obtain a qualitative data from an ordinal or a rating scale performed by three judges and these parameters were subjected to non-parametric test. In the present study variables with minimum of three subjects were considered even for non-parametric analysis.

The statistical results and discussions related to effect of surgery on speech characteristics of individuals with VPD were profiled based on the speech characteristics such as articulation, resonance, speech intelligiblity and voice. The salient findings of the study are discussed in the following sections

4.1 Effect of surgery on articulatory characteristics of individuals with VPD were studied under the following three subsections

4.1.1 Percentage of articulatory errors across conditions

4.1.2 Articulatory errors of SODA in percentage

4.1.3 Compensatory articulatory errors

4.2 Effect of surgery on resonance characteristics of individuals with VPD were studied under the following subsections

4.2.1 Instrumental assessment of resonance characteristics across conditions

4.2.2 Perceptual resonance characteristics across conditions

4.3 Effect of surgery on speech understandability of individuals with VPD across conditions.

4.3.1 Perceptual assessment of speech understandability

4.3.2 Percentage of speech intelligiblity (PSI)

4.4 Effect of surgery on Dysphonia Severity Index (DSI) of individuals with VPD across conditions.

4.4.1 Dysphonia severity index (DSI) in Children

4.4.2 Dysphonia severity index (DSI) in Adults

4.5 Comparison of perceptual and Instrumental evaluation of resonance in individuals with VPD across conditions

4.5.1 Relationship between nasalance values and perceptual resonance characteristics

4.5.2 Relationship between velopharyngeal closure and nasalance values

4.1 Effect of Surgery on Articulatory Characteristics of Individuals with VPD

The results of articulatory characteristics of individuals with VPD are described in this section. The results were grouped based on the types of articulatory error analysis which include overall articulation errors, articulation errors based on SODA and compensatory articulation.

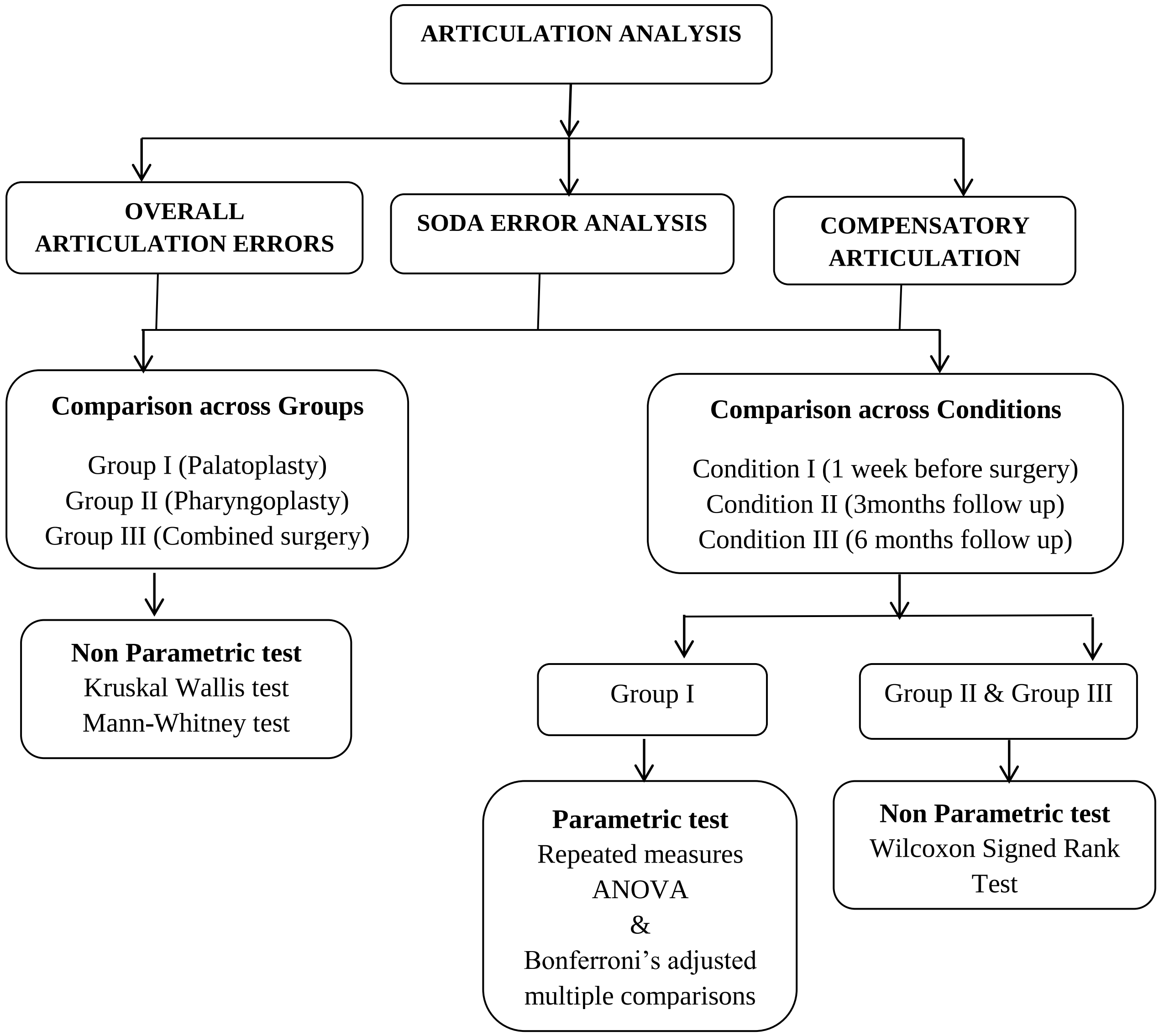


Figure 4. Flow chart for summarizing analysis of articulation errors

4.1.1. Percentage of Articulation Errors

The mean, standard deviation and median for articulation errors (%) of different types of surgery across conditions are represented in Table 2. The results showed that overall mean percentage of articulation errors decreased for condition III(6 months follow up) compared to condition I (pre-operative) and II (3 months follow up). Among the groups (types of surgery), group II (pharyngoplasty) had reduced errors followed by group I (palatoplasty) and II (combined surgery) across conditions.

Table 2

Mean, Standard Deviation and Median for Articulation Errors (%) across Conditions

Type of Surgery	**Articulation Errors (%)**											
	N	**Condition I**			**N**	**Condition II**			**N**	**Condition III**		
		M	***SD***	***Mdn***		***M***	***SD***	***Mdn***		***M***	***SD***	***Mdn***
G I	18	41.88	12.01	42.50	18	36.38	10.09	40.00	10	24.50	8.95	27.50
G II	8	27.12	9.22	26.00	8	25.62	9.79	25.00	4	17.50	6.45	17.50
G III	4	31.25	13.76	32.50	4	30.00	9.12	30.00	1	30.00*	-	30.00
Total	30	31.25	14.29	37.50	30	32.66	11.1	32.50	15	23.00	8.61	25.00

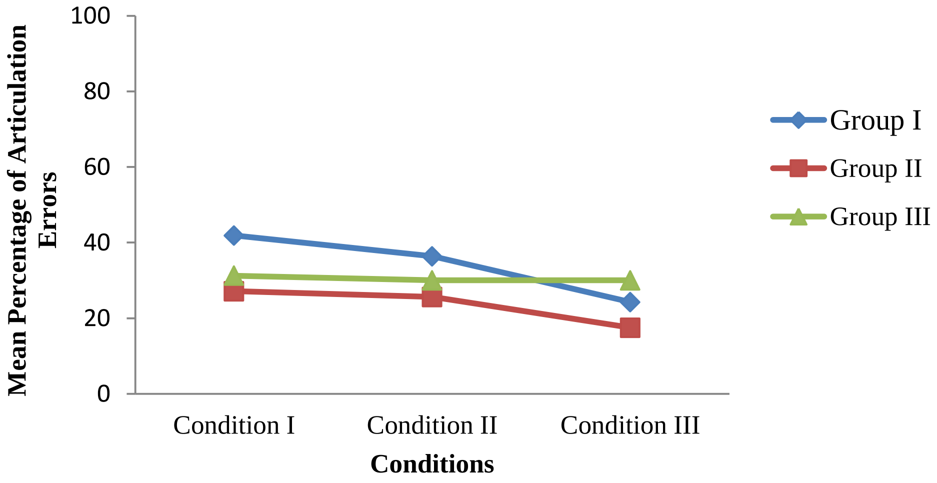
Note. [M=Mean, SD= standard deviation, Mdn= Median, GI = Group I (Palatoplasty), G II = Group II (Pharyngoplasty), G III = Group III (Combined Surgery), N= no. of subjects, * = Single subject's data, - = No standard deviation]

4.1.1.1 Comparison across groups

Kruskal Wallis test was done to find significant difference across groups on articulation errors for condition I and II. The results showed that there was no significant difference across groups (types of surgery) in percentage of articulation errors for conditions [Condition I χ^2 (2) = 2.40, $p > 0.05$, Condition II χ^2 (2) = 5.30, $p > 0.05$]. For condition III, Mann-Whitney test was done to find significant difference across groups I and II. The test results showed that there was no significant deference between groups I and II for condition III [G I – G II ($|z|$ = 0.17, $p > 0.05$)]. Kruskal Wallis test could not be done for condition III because only one subject data was present for condition III of group III. The data showed that condition III of group III had greater errors followed by group I and group II.

4.1.1.2 Comparison across conditions

Among the types of surgery, group I (palatoplasty) followed a normal distribution and to determine main effects for conditions on percentage of articulation errors, repeated measures ANOVA was carried out. The results revealed that effect of conditions on articulation errors was significant [$F (2, 18) = 35.51$, $P < 0.001$] with effect size $\eta_p^2 = 0.89$. Post hoc test using Bonferroni correction revealed that there was no significant difference between condition I and II ($p>0.05$). However, a significant difference ($p<0.05$) was observed for condition III (6 months follow up) when compared with condition I and II. Figure 5 shows the effect of type of surgery on overall articulation errors (%) across conditions.



[Group I - Palatoplasty, Group II –Pharyngoplasty, Group III- Combined Surgery, Condition I – Pre surgery, Condition II – 3 months follow up, Condition III – 6 months follow up]

Figure 5. Effect of type of surgery on overall articulation errors (%) across conditions.

Figure 5 depicts the mean scores for three different types of surgery across conditions. Group I had significant difference across conditions followed by group II and group III mean values did not vary significantly across conditions.

Wilcoxon’s signed rank test was done to see if there is any significant difference across conditions for Group II and III (Table 3).

Table 3

Results of Wilcoxon’s Signed Rank Test for Articulation Errors across Conditions for groups II and III.

Conditions	**Types of Surgery**	
	G II	**G III**
	|z|	**|z|**
C I-C II	0.75	0.57
C I- C III	1.84	-
C II- C III	1.84	-

Note. P > 0.05 [Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3months follow up, Condition III (CIII) = 6 months follow up]

The results showed that there was no significant difference between the conditions for group II and III (p > 0.05). For group II (pharyngoplasty) and III (combined surgery) Friedman test could not be done to find overall difference because there were less than three subjects in the condition III (6 months follow up) of group III. The data obtained showed that condition III does not vary when compared to condition I and II for both the groups.

4.1.2 Articulation Errors based on SODA (%)

The mean, standard deviation and median for articulatory errors based on SODA across groups and conditions are represented in Table 4. The articulation errors were classified based on perceptual analysis. They were categorized as substitution, omission, distortion and addition. In general, the percentage of errors was more in condition I (pre-operative) and reduced in the post-operative conditions (condition II & III). The articulatory errors were predominantly characterized by substitution errors followed by distortion and omission errors. As addition types of articulatory errors were not seen in the subjects the same was not considered in this study. Among the types of surgery, group II (pharyngoplasty) had reduced SOD errors in the condition III (6 months followup) followed by group III (combined surgery).

Table 4

Mean , Standard Deviation and Median of SOD Errors (%) across Conditions

Type of Surgery	SOD Errors (%)											
	N	C I (N=30)			N	C II (N=30)			N	C III (N=15)		
		M	***SD***	***Mdn***		***M***	***SD***	***Mdn***		***M***	***SD***	***Mdn***
						Substitution						
G I	18	27.50	6.90	27.50	18	21.11	6.54	20.00	10	16.00	5.16	15.00
G II	8	20.50	7.25	19.00	8	17.62	4.56	18.00	4	10.00	4.08	10.00
G III	4	24.50	8.42	25.00	4	22.50	6.45	22.50	1	15.00*	-	15.00
Total	30	25.20	7.57	25.00	30	20.36	6.12	20.00	15	14.30	5.30	15.00
						Distortion						
GI	18	10.22	3.71	10.00	18	10.55	3.79	10.00	10	6.67	3.53	5.00
G II	8	7.87	5.48	7.50	8	8.00	5.39	7.50	4	6.67	2.88	5.00
G III	4	6.25	4.78	7.50	4	7.50	2.88	7.50	1	10.00*	-	10.00
Total	30	9.06	4.47	10.00	30	9.40	9.46	10.00	15	6.92	3.00	5.00
						Omission						
G I	18	4.44	4.10	5.00	18	5.38	4.92	5.00	10	5.00	2.52	5.00
G II	8	-	-	-	8	-	-	-	4	5.00	2.32	5.00
G III	4	1.00	0.50	0.00	4	-	-	-	1	5.00*	-	5.00
Total	30	3.85	2.73	-	30	3.50	4.70	-	15	5.00	-	5.00

Note. [M= Mean, SD= standard deviation, Mdn= Median, Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3months follow up, Condition III (CIII) = 6 months follow up, *= Single subject's data, N= No. of subjects, - = No data / No Standard deviation]

4.1.2.1 Comparison across groups

Kruskal Wallis test was done to find if there was any significant difference across groups (types of surgery) on articulation errors based on SODA analysis for condition I and II (Table 5).

Table 5

Results of Kruskal Wallis Test for SOD errors across Groups I and II.

Parameters	**Conditions**	
	C I	**C II**
	χ^2 (df =2)	**χ^2 (df=2)**
Substitution	4.20	1.90
Distortion	2.92	2.93
Omission	9.31*	12.06*

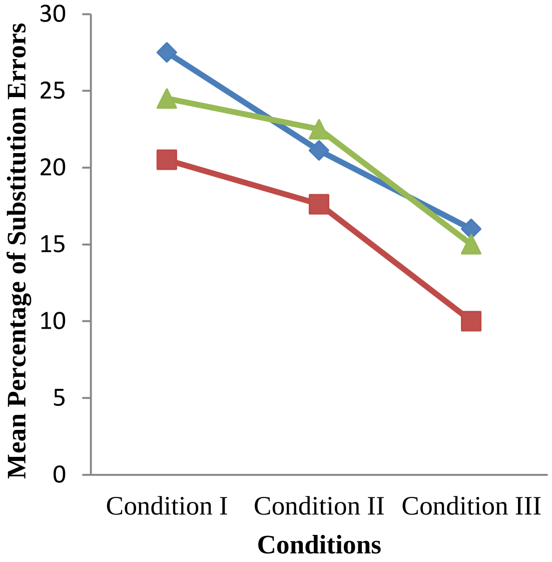
Note. * $P < 0.05$ [Condition I (CI) – Pre surgery, Condition II (CII) – 3 months follow up]

The results indicated significant difference ($p<0.05$) for omission errors between types of surgery on condition I (pre surgery) and condition II (3 months follow up). There was no significant difference between the groups on other errors such as substitution and distortion. Mann-Whitney U test was done for condition I and II for omission errors across types of surgery. The results showed that significant difference was observed for condition II omission errors when group I (palatoplasty) was compared with other two groups [pharyngoplasty ($|z| =2.94$, $p<0.05$); combined surgery group ($|z| =2.19$, $p<0.05$)]. For condition I omission errors the test results depicted significant difference between group I and II ($|z| =2.75$, $p<0.05$).

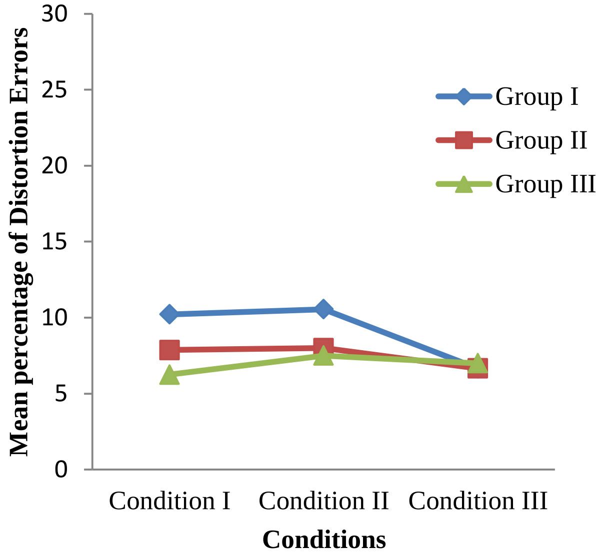
Mann-Whitney test was done to find significant difference across groups I and II for condition III of SOD errors. The test results showed that there was no significant deference between groups I and II for condition III of substitution [G I – G II ($|z| = 1.83$, $p > 0.05$)], omission [G I – G II ($|z| = 1.00$, $p > 0.05$)] and distortion errors [G I – G II ($|z| = 0.24$, $p > 0.05$)]. Kruskal Wallis test could not be done for condition III because only one subject data was present for condition III of group III. The data showed that condition III of group III did not vary much for omission and substitution errors when compared with group I and group II. Overall distortion errors significantly reduced in condition III (6 months follow up) when compared with condition I (pre surgery) and II (3 months follow up).

4.1.2.2 Comparison across conditions

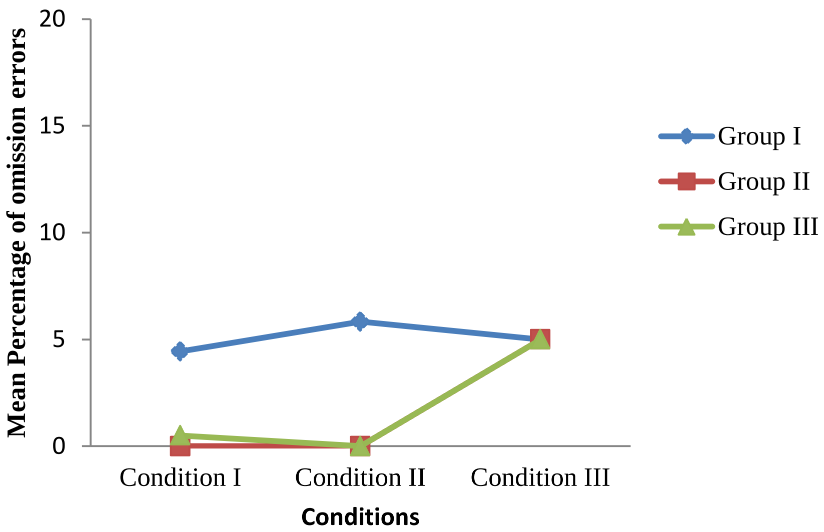
Among the types of surgery, palatoplasty (Group I) followed a normal distribution, so a repeated measures ANOVA was done to determine main effect of conditions on SOD errors. The results revealed significant main effect of conditions on substitution errors [$F (2, 6) =18.60$, $P < 0.001$; Effect size ($\eta_p^2 = 0.86$)] but not for omission [$F (2, 6) = 4.50$, $P > 0.05$; Effect size ($\eta_p^2 = 0.60$)] and distortion errors [$F (2, 6) =12.05$, $P > 0.05$; Effect size ($\eta_p^2 = 0.40$)]. Post hoc test using Bonferroni's correction was done for substitution errors and the results revealed that there was significant difference between condition I and III ($p < 0.05$). However, a significant difference ($p>0.05$) was not observed for condition II (3 months follow up) when compare with condition I and II.



(a)



(b)



(c)

[Group I - Palatoplasty, Group II–Pharyngoplasty, Group III - Combined Surgery, Condition I– Pre surgery, Condition II– 3 months follow up, Condition III– 6 months follow up]

Figure 6. Effect of type of surgery on mean percentage scores of [(a) - substitution, (b)-distortion errors and (c) - omission errors).

Figure 6 showed the mean percentage of SOD errors across groups and conditions. Among the SOD errors, substitutions were more followed by distortions and omissions. Group II showed reduced errors followed by group III and I.

For group II (pharyngoplasty) and III (combined surgery) Wilcoxon's signed rank test was done to investigate significant difference between conditions for articulation errors based on SOD analysis (Table 6).

Table 6

Results of Wilcoxon's Signed Rank Test for Articulation Errors (SOD) across conditions

Conditions		**Types of Surgery**	
		G II	**G III**
		|z|	**|z|**
C I-C II	S	1.84	1.34
	O	1.00	1.00
	D	0.27	1.00
C I-C III	S	1.84	-
	O	-	-
	D	-	-
C II - CIII	S	1.84	-
	O	-	-
	D	0.44	-

Note: P > 0.05 [S=Substitution, O=Omission, D=Distortion, Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up]

The results showed that for group II (pharyngoplasty) there was no significant difference between conditions on all SOD (substitutions, omission and distortion) types of errors. In group III (combined surgery), no significant difference was seen between condition I and II on SOD errors. Friedman test could not be done because of less than three subjects in the condition III (6 months follow up) of group III (combined surgery). The data showed that both distortion and omission errors of condition III were found to be greater than that of condition II (3 months follow up) but less that the scores of condition I (pre surgery).

4.1.2 Compensatory Articulatory Errors

The articulatory characteristics of individuals with VPD was further analysed based on compensatory articulation. The compensatory articulatory errors were further grouped under three categories such as backing errors to post uvular place, backing errors to oral place and articulation errors due to nasalization.

4.1.3.1 Backing errors to post uvular place of articulation

The mean, standard deviation and median for backing errors to post uvular place across groups and conditions are represented in Table 7. The results showed that glottal stops [ʔ] were found to be to be greater followed by pharyngeal fricatives [ʕ] and Pharyngeal stops across all conditions. Among the types of surgery, group II (pharyngoplasty) had reduced backing errors to post uvular place across all conditions followed by group III (combined surgery) and group I (palatoplasty).

Table 7
Mean, Standard Deviation and Median of Backing Errors to Post Uvular Place (%)

Type of Surgery	Backing Errors from Oral to Post Uvular Place (%)											
		Condition I				Condition II				Condition III		
	N	*M*	*SD*	*Mdn*	N	*M*	*SD*	*Mdn*	N	*M*	*SD*	*Mdn*
						Glottal Stops						
GI	18	11.42	4.56	10.00	18	9.16	3.58	10.00	10	5.71	1.88	5.00
G II	8	10.00	4.08	10.00	8	7.50	2.50	7.5	4	5.00	0.00	5.00
G III	4	12.50	3.53	12.50	4	12.50	3.53	12.5	1	5.00*	-	5.00
Total	30	11.25	4.25	10.00	30	9.00	4.47	10.00	15	5.50	1.58	5.00
						Pharyngeal Stops						
G I	18	10.41	3.96	10.00	18	9.16	3.58	10.00	10	6.67	2.58	5.00
G II	8	5.00	0.00	5.00	8	3.75	2.50	5.00	4	5.00	0.00	5.00
GIII	4	-	-	-	4	-	-	-	1	-	-	-
Total	30	9.06	4.17	10.00	30	7.81	4.06	7.50	15	6.87	2.58	5.00
						Pharyngeal Fricatives						
G I	18	10.71	3.45	10.00	18	8.12	2.58	10.00	10	6.67	2.88	5.00
G II	8	-	-	-	8	-	-	-	4	-	-	-
G III	4	-	-	-	4	-	-	-	1	-	-	-
Total	30	10.71	3.45	10.00	30	8.12	2.58	10.00	15	6.67	2.88	5.00

Note. [M= Mean, SD= standard deviation, Mdn= Median, Group I (GI) - Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3months follow up, Condition III (CIII) = 6 months follow up, N= no. of subjects, * = Single subject's data, - = No data / No Standard deviation]

4.1.3.1.1 Comparison across groups

Kruskal Wallis test was done to find if there was any significant difference between groups on backing errors to post uvular place across conditions I and II (Table 8).

Table 8

Results of Kruskal Wallis Test for Backing Errors to Post Uvular Place

Parameters	**Conditions**	
	Condition I	**Condition II**
	χ^2 (df =2)	**χ^2 (df=2)**
Glottal stops	0.55	2.23
Pharyngeal stops	5.45	5.51*

Note. * P < 0.05 [Condition I- Pre surgery, Condition II – 3 months follow up]

The results showed that there was a significant difference across groups on condition II (3 months follow up) for pharyngeal stops. Mann-Whitney U test was done for condition II (3 months follow up) scores of pharyngeal stops across groups. The results showed that significant difference was observed for pharyngeal stops of condition II between group I and II ($|z|=2.33$, $p<0.05$). But no significant difference was seen between groups for glottal stops [ʔ] across conditions.

Mann-Whitney test was done to find significant difference across groups I and II for condition III of glottal and pharyngeal stops. The pharyngeal fricatives [ʕ] were absent in condition III for group II and III. Hence, statistical analysis could not be carried out for pharyngeal fricatives. The test results indicated that there was no significant deference between groups I and II for condition III of glottal stops [G I – G II ($|z| = 0.53$, $p > 0.05$)] and pharyngeal stops [G I – G II ($|z| = 0.63$, $p > 0.05$)]. Kruskal Wallis test could not be done for condition III because only one subject data was present for condition III of group III for all the backing errors. The data showed that condition III of group III did not vary much for glottal stops.

4.1.3.1.2 Comparison across conditions

For compensatory articulatory errors all the three groups does not follow normal distribution Hence, Wilcoxon's signed rank test was done to investigate significant difference between conditions for backing errors to post uvular place across groups (Table 9).

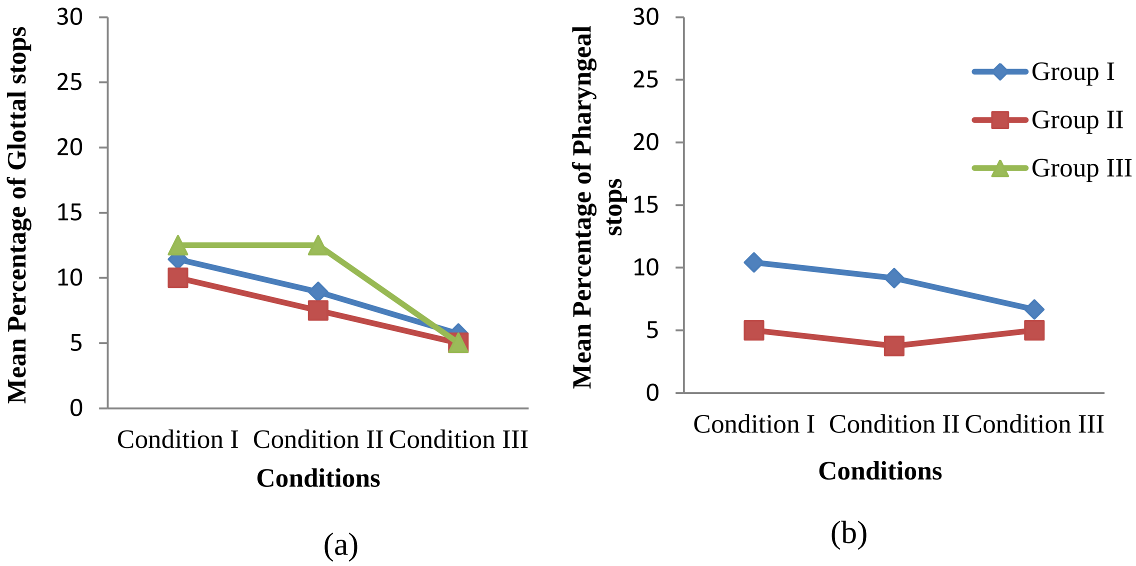
Table 9

Results of Wilcoxon's Signed Rank Test for Backing Errors to Post Uvular Place across conditions

Conditions		**Types of Surgery**		
		G I	**G II**	**G III**
		|z|	**|z|**	**|z|**
C I- C II	GS	2.33**	1.41	1.34
	PhS	1.89	1.00	1.00
	PhF	2.52**	0.27	1.00
C I- C III	GS	2.46**	1.41	-
	PhS	2.23**	-	-
	PhF	2.12**	-	-
C II-C III	GS	2.12**	2.12	-
	PhS	1.63	-	-
	PhF	2.01*	0.44	-

Note. **P<0.01 * P < 0.05, [Group I (GI) - Palatoplasty, Group II (GII) –Pharyngoplasty, Group III (GIII) - Combined Surgery, Condition I (CI) – Pre surgery, Condition II (CII) – 3 months follow up, Condition III (CIII) – 6 months follow up, GS- Glottal Stops , PhS-Pharyngeal Stops, PhF-Pharyngeal Fricatives]

The results showed a significant difference between all the conditions for glottal stops [ʔ] and pharyngeal stops for group I (palatoplasty). For group II (pharyngoplasty), there was no significant difference for backing errors to post uvular place between conditions. For group III (combined surgery), there was no significant difference between condition I (pre surgery) and II (3 months follow up). Frideman test could not be done compare across conditions because condition III (6 months follow up) for group III had less than three subjects.



[GI - Palatoplasty, GII –Pharyngoplasty, GIII- Combined Surgery, Condition I – Pre surgery, Condition II – 3 months follow up, Condition III – 6 months follow up]

Figure 7. Effect of types of surgery on mean scores of (a- glottal stops and b- Pharyngeal stops).

Figure 7 indicates that mean scores for glottal stops and pharyngeal stops. The mean values for glottal stops were found to be greater than that of pharyngeal stops. The data showed reduced scores for condition III of glottal stops than condition I and II. There were no pharyngeal stops and fricatives seen in the condition III (6 months post surgery).

4.1.3.2 Backing errors to oral place of articulation

The mean, standard deviation and median for backing errors to oral place of the different types of VPD surgery across three conditions for individuals with VPD surgery are represented in Table10. The results showed that velar stops were found to be to be greater followed by palatal stops across all conditions. Among the types of surgery, pharyngoplasty (Group II) had reduced backing errors to post oral place for all the three conditions followed by group I (palatoplasty) and III (combined surgery group).

Table 10

Mean, Standard Deviation and Median for Backing Errors to Oral Place across Conditions.

Type of Surgery	N	Backing Errors to Oral Place (%)										
		C I				C II				C III		
		M	***SD***	***Mdn***	**N**	***M***	***SD***	***Mdn***	**N**	***M***	***SD***	***Mdn***
						Palatal stops						
G I	18	8.33	4.08	7.50	18	7.50	4.18	5.00	10	10.00	0.00	10.00
G II	8	5.33	2.58	5.00	8	5.00	3.16	5.00	4	5.00	0.00	5.00
G III	4	10.0	7.07	10.00	4	7.50	3.53	7.50	1	-	-	-
Total	30	7.28	4.02	5.00	30	6.42	3.63	5.00	15	7.50	3.53	7.50
						Velar stops						
G I	18	10.00	5.00	10.00	18	10.00	5.00	10.00	10	10.00	0.00	10.00
G II	8	-	-	-	8	-	-	-	4	5.00	0.00	5.00
G III	4	-	-	-	4	-	-	-	1	5.00*	-	5.00
Total	30	10.00	5.00	10.00	30	10.00	5.00	10.00	15	6.67	2.88	5.00

Note. [M= Mean, SD= standard deviation, Group I (GI) = Palatoplasty, Group II (GII) =Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I(CI) = Pre surgery, Condition II (CII) = 3months follow up, Condition III (CIII) = 6 months follow up, N= no. of subjects, * = Single subject's data, - = No data / No Standard deviation]

4.1.3.2.1 Comparison across groups

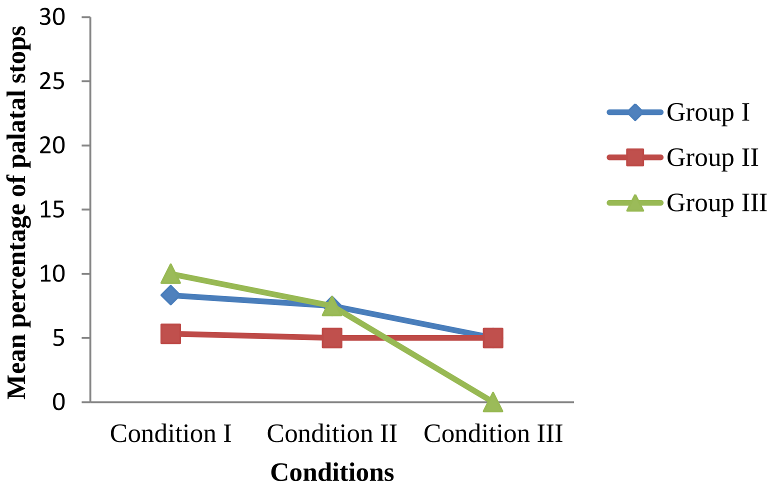
Kruskal Wallis test was done to find if there was any significant difference across groups on backing errors to oral place of articulation for conditions I and II. The results showed that there was no significant difference between groups on backing errors to oral place such as palatal [condition I χ^2 (2) = 1.51, p > 0.05; Condition II χ^2 (2) = 1.00, p > 0.05] and velar stops [Condition II χ^2 (2) = 2.10, p > 0.05; Condition II χ^2 (2) = 3.56, p > 0.05] across conditions.

Mann-Whitney test was done to find significant difference across groups I and II for condition III of palatal stops and velar stops. The test results indicated that there was no significant deference between groups I and II for condition III of palatal stops [G I – G II (|z| = 1.00, p > 0.05)] and velar stops [G I – G II (|z| = 1.00, p > 0.05)]. The palatal stops were absent in condition III of III. Hence, statistical analysis could not be carried out for velar stops. Kruskal Wallis test could not be done for because condition III of group III had only one subject data. The data showed that condition

III scores of velar stops in group III was lesser compared to condition III scores if group I.

4.1.3.2.2 Comparison across conditions

Wilcoxon's signed rank test was done to find any significant difference between conditions for backing errors across different types of surgery.



[GI - Palatoplasty, GII –Pharyngoplasty, GIII- Combined Surgery, Condition I – Pre surgery, Condition II – 3months follow up, Condition III – 6 months follow up]

Figure 8. Effect of type of surgery on mean scores of palatal stops across conditions.

The results showed that there was no significant difference between condition I and II on mean scores of presence palatal stops for group I [CI- CII ($|z|=1.0$, $p>0.01$)], group II [CI-CII ($|z|=1.0$, $p>0.01$)] and group III [CI-C II ($|z|=1.0$, $p>0.01$)]. Friedman test could not be done because condition III of palatal stops and all the three conditions of velar stops because of less than three subjects in that group. The data obtained revealed that palatal stops reduced in the condition III but velar stops increased compared to condition I and II.

4.1.3.3 Articulation errors due to nasalization

The mean, standard deviation and median for articulation errors due to nasalization (%) across groups and conditions are represented in Table 11. The percentage of weak oral pressure consonants was found to be higher than other errors and the least was substitution of nasal consonants for oral consonants. Among the types of surgery, group II (pharyngoplasty) had reduced articulation errors due to nasalization for all the three conditions followed by group III (combined surgery) and group I (palatoplasty).

Table 11

Mean, Standard Deviation and Median for Articulation Errors due to Nasalization (%) across Conditions

Type of Surgery	Articulation Errors due to Nasalization (%)											
		Condition I				Condition II				Condition III		
	N	***M***	***SD***	***Mdn***	***N***	***M***	***SD***	***Mdn***	**N**	***M***	***SD***	***Mdn***
						Nasal Fricatives						
GI	18	10.41	3.96	10.00	18	9.58	2.57	10.00	10	8.00	4.47	5.00
G II	8	7.85	3.93	5.00	8	5.71	1.88	5.00	4	5.00	-	5.00
GIII	4	11.25	4.78	12.50	4	11.67	2.88	12.50	1	-	-	-
Total	30	9.78	4.12	10.00	30	8.63	10.00	10.00	15	7.50	3.53	5.00
						Nasalization of Oral Consonants						
G I	18	12.50	3.53	10.00	18	9.58	2.57	10.00	10	6.87	2.58	5.00
G II	8	6.66	2.58	5.00	8	5.71	1.88	5.00	4	5.00	-	5.00
G III	4	11.66	2.88	10.00	4	11.67	2.88	10.00	1	-	-	-
Total	30	10.52	4.04	10.00	30	8.63	10	10.00	15	6.50	2.41	5.00
						Substitution of Nasal for Oral Consonants						
GI	18	7.22	2.63	5.00	18	6.81	2.52	5.00	10	7.50	3.53	5.00
G II	8	8.33	2.88	10.00	8	7.50	2.88	7.50	4	5.00	-	5.00
G III	4	-	-	-	4	-	-	-	1	-	-	-
Total	30	7.50	2.61	7.50	30	7.00	2.53	5.00	15	6.42	2.63	5.00
						Weak Oral Pressure Consonants						
G I (18)	18	30.00	8.74	30.00	18	26.67	10.14	25.00	10	16.50	6.68	17.50
G II (8)	8	20.00	8.86	22.50	8	17.50	6.54	20.00	4	11.20	4.78	12.50
G III (4)	4	25.00	7.07	22.50	4	25.00	7.07	22.50	1	20.00*	-	20.00
Total	30	26.66	9.40	25.00	30	24.00	9.59	20.00	15	15.30	6.39	15.00

Note· [M= Mean, SD= standard deviation, Mdn= Median Group I (GI) = Palatoplasty, Group II(GII) =Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I(CI) = Pre surgery, Condition II (CII) = 3months follow up, Condition III (CIII) = 6 months follow up, N= no. of subjects, * = Single subject's data , - = No data / No Standard deviation]

4.1.3.3.1 Comparison across groups

Kruskal Wallis test was done to find significant difference between groups (types of surgery) on errors due to nasalization for conditions I and II (Table 12).

Table 12

Results of Kruskal Wallis Test for Articulation Errors due to Nasalization across groups

Parameters	**Conditions**	
	C I	**C II**
	χ^2 (df =2)	**χ^2 (df=2)**
NF	2.58	3.99
NOC	8.86*	10.40*
SNOC	0.40	0.21
WOPC	5.14	4.66

Note. * P < 0.05 [NF=Nasal Fricatives, NOC=Nasalisation of Oral consonants, SNOC= Substitution of Nasal for Oral consonants, WOPC =Weak Oral Pressure Consonants, Condition I (CI) = Pre surgery, Condition II (CII) = 3months follow up, Condition III (CIII) = 6 months follow up]

The results showed that there was a significant difference between groups on condition II (3 months follow up) scores for nasalization of oral consonants. Mann-Whitney U test was done for condition II for nasalization of oral consonants across different groups. The results showed significant difference for condition I scores in nasalization of oral consonants between [Group I and II ($|z|$=2.82, $p<0.05$); Group II and III ($|z|$=2.47, $p<0.05$)] types of surgery. Kruskal Wallis test results depicted no significant difference between groups for condition I and II on articulation errors such as substitution of nasal for oral consonants, nasal fricatives and weak oral pressure consonants

Mann-Whitney test was done to find significant difference across groups I and II for condition III of nasalization errors. The test results indicated that there was no significant deference between groups I and II for condition III of nasal Fricatives [G I – G II ($|z|$ = 0.69, $p > 0.05$)] , nasalization of oral consonants [G I – G II ($|z|$ = 0.98, $p > 0.05$)], substitution of nasal for oral consonants [G I – G II ($|z|$ =1.41, $p > 0.05$)]and weak oral pressure consonants [G I – G II ($|z|$ = 1.37, $p > 0.05$)]. Kruskal Wallis test could not be done because Condition III of group III had no nasalization errors.

4.1.3.3.2 Comparison across conditions

Wilcoxon's signed rank test was done to investigate significant difference between conditions for errors due to nasalization across different types of surgery (Table 13).

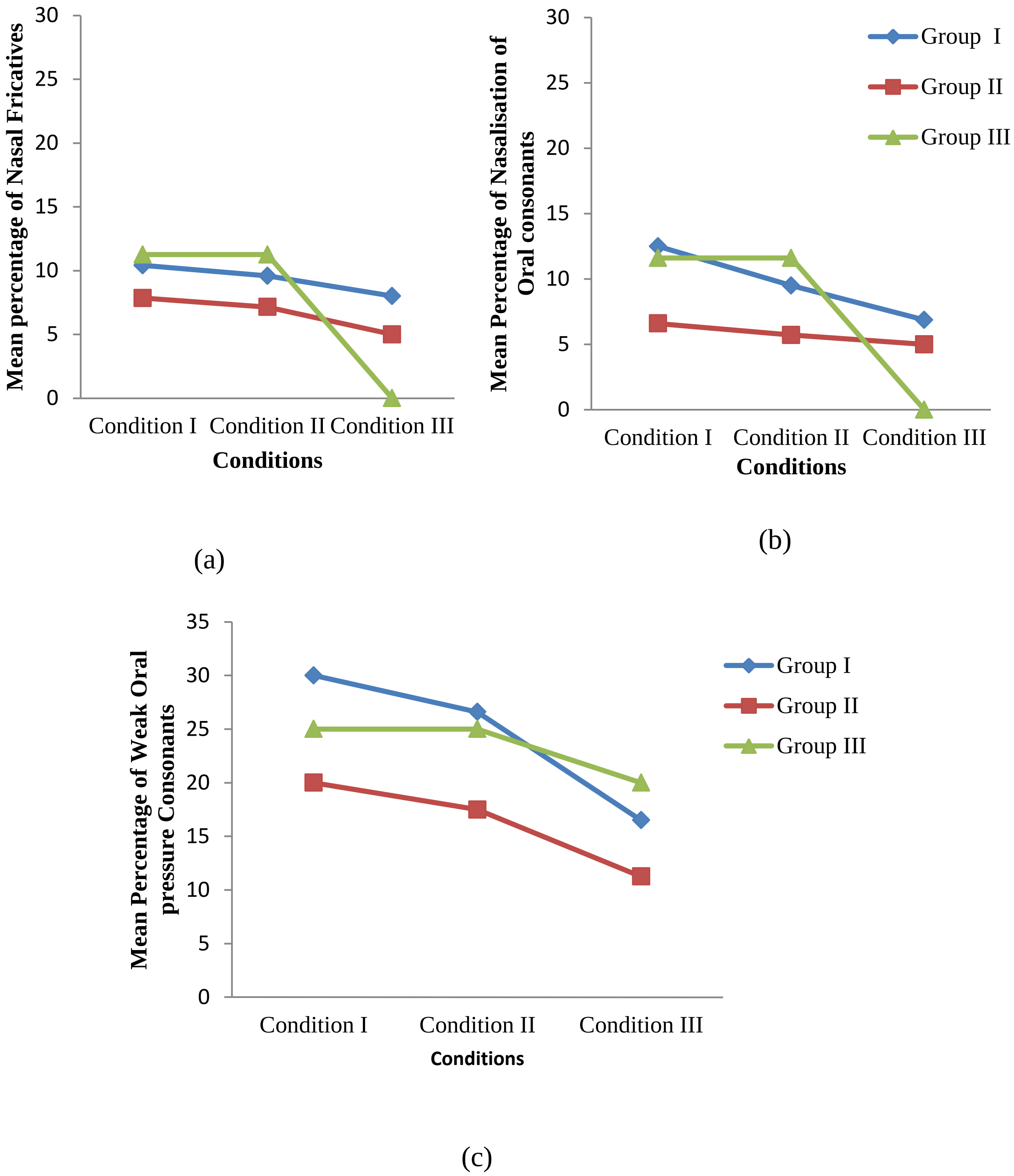
Table 13

Results of Wilcoxon's Signed Rank Test for Nasalization Errors across conditions

Conditions		**Types of Surgery**		
		G I	**G II**	**G III**
		|z|	**|z|**	**|z|**
C I-C II	NF	1.00	1	-
	NOC	2.12*	1	-
	SNOC	-	-	-
	WOPC	2.58**	1.63	-
C I- C III	NF	2.0*	1.84	-
	NOC	1.41	-	
	SNOC	-	1	-
	WOPC	2.83**	1.63	-
C II- C III	NF	1.00	1.84	-
	NOC	1.73	-	-
	SNOC	-	1	
	WOPC	2.68**	1.64	-

Note. **P<0.01 * P < 0.05 [Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3months follow up, Condition III (CIII) = 6 months follow up, NF= Nasal Fricatives, NOC=Nasalisation of Oral consonants, SNOC = Substitution of Nasal for Oral consonants, WOPC = Weak Oral Pressure Consonants]

In the group I (palatoplasty), weak oral pressure consonants showed significant difference between all the conditions. For, nasalisation of oral consonants there was a significant difference between condition I and II. For nasal fricatives there was a significant difference between condition I (pre surgery) and II (3 months follow up) in the group I. For group II (Pharyngoplasty) and III (combined surgery), significant difference was not seen for articulation errors due to nasalization between conditions. Friedman test could not be done to compare across conditions because of no nasalization errors present for condition III of group III.



[GI - Palatoplasty, GII –Pharyngoplasty, GIII- Combined Surgery, Condition I – Pre surgery, Condition II – 3months follow up, Condition III – 6 months follow up]

Figure 9. Effect of Type of surgery on articulation errors due to nasalization (a- Nasal Fricatives, b-Nasalization of oral consonants, c- weak oral pressure consonants)

Figure 9 indicates the mean scores of nasalization errors across groups and conditions. The weak oral pressure consonants were found to have greater percentage among all the nasalization errors.

4.1.4 Discussion

The individuals with VPD were analyzed for articulation characteristics across conditions and groups. The overall mean percentage for presence or absence of articulation errors was calculated by using a binary rating scale (0 or 1). The results indicated that percentage of overall articulatory errors were more in pre-operative condition of individuals with VPD. This indicates that misarticulation is one of the main characteristics of speech in individuals with VPD. The presence of misarticulation in these individuals is due to abnormalities in oronasal structure / function, orofacial structure and growth, learned neuromotor patterns during early childhood, and / or disturbed psychosocial development (Grunwell & Sell, 2002). These structural abnormalities results in inadequate velopharyngeal closure which further leads to reduced air pressure during production of stops and other pressure consonants. This anatomical alteration results in compensated articulatory behaviour. This supports the findings of earlier literature (Trost Cardamone, 1998; Kummer, 2001; Elbarbary et al., 2008; Van Lierde et al., 2008; Nagarajan, Savitha & Subramanian, 2009) who reported the presence of misarticulation in individuals with VPD.

The results also indicated that the mean percentage of articulatory errors reduced post – operatively and in subsequent follow up. This may be due to the effect of surgical management of VPD which alters the function of the muscles to certain extent. The observed changes are the result of the structural modifications made to the muscles of the soft palate during surgery. The changes in the morphology of the muscles directly contribute for the improvement in the articulation to certain magnitude. The results of the present study supports the findings by Tonz et al. (2002) , Meek et al. (2003), Elbarbary et al. (2008) and Van Lierde et al.(2008) who reported reduction in articulation errors post operatively.

The articulatory errors analysed based on SODA indicated the presence of more of substitution errors followed by distortion and omission errors. The substitution errors are due to VPD which results in loss of air through the velopharyngeal port and also due to incorrect placement of tongue in the oral cavity during the production of pressure consonants. The above results support the findings of Bzoch (1968) who also reported that substitution errors occurred more frequently in the speech of individuals with VPD followed by distortion and omission errors. But results of the present study contradict the findings by Van Denmark (1979) who reported more oral distortions followed by substitutions and omissions. This discrepancy in the classification of errors between substitution and distortion was difficult because of the criteria used by the investigators. Some investigators (Bzoch, 1956; Counihan, 1956; Starr, 1956) have classified pharyngeal fricatives as substitution while others have classified it as distortions because these phonemes are not a part of English language. In this study, all the participants were above 7 years of age and none of them had any developmental articulatory errors. The SODA errors were mostly associated with compensatory articulatory errors such as pharyngeal fricatives [ʕ], glottal [ʔ] and pharyngeal stops which were due to VPD.

Among the groups, pharyngoplasty group had reduced over all articulation errors and SOD errors in all the three conditions followed by combined surgery and palatoplasty group. The subjects in group II and III were adolescent and adult subjects and their pre-operative articulation errors were less compared to palatoplasty group. The other factors which would have contributed to the reduced articulatory errors is the effectiveness of the secondary palatal repair, dental alignments, status of the tonsils and adenoids (Kuehn & Moller, 2000; Kummer, 2001). The results of the present study were in consonance with the study done by Sobye et al. (2004) who reported the outcomes of pharyngoplasty in twenty four individuals with VPD older than 12 years and best results were seen in adolescent individuals secondary to cleft of palate only.

The compensatory articulatory errors of individuals with VPD have been grouped into three categories. They are backing errors to post uvular place of articulation, backing errors to post oral place of articulation and nasalization errors (Henningsson et al., 2008). The results showed that among the backing errors, glottal stops were more followed by pharyngeal fricatives [ʕ] and pharyngeal stops. The glottal stops [ʔ] were predominately substituted for plosives (Golding-Kushner, 1995; Witzel, 1995; Kummer, 2001) and pharyngeal fricatives [ʕ] for fricatives and affricates (Trost-Cardamone, 1997; Golding-Kushner, 2001). In these backing errors, the manner remains the same only the place of articulation changed from oral to post uvular because of the structural impairments caused by the cleft or the inadequate velopharyngeal closure. This finding is consistent with previous reports in the literature (Mc Donald & Baker, 1951; Morley, 1954; Bzoch, 1971).

The glottal stops [ʔ] and pharyngeal fricatives [ʕ] are considered as frequently occurring backing errors (Kuehn & Moller, 2000; Peterson-Falzone et al., 2001) because the place of production of these sounds are well below the velopharyngeal port (Trost, 1987; Bzoch, 1971; Morris, 1971; Lawrence & Philips, 1975). The most common explanations for backing errors was present or past VPD (Peterson-Falzone, 1986; Chapman, 1993; D'Antonio & Scherer, 1995; McWilliams et al., 1990) and current or past oronasal fistulae (Hoch, Golding-Kushner, Siegel-Sadowitz, & Shprintzen, 1986; LeBlanc, 1996). In VPD, the speaker subconsciously attempting to achieve valving at a point inferior to the velopharyngeal valve, in an effort to produce plosion or frication before pressure is lost through the velopharyngeal port. These backing errors are mostly associated with hypernasality and nasal air emission because of the open velopharyngeal port during the production of these sounds. The articulation movements of these error patterns involve the habituation of coordinated patterns of neural integration very different from that involved in the normal developmental patterns (Bzoch, 1964; Peterson-Falzone et al., 2001).

Among the articulation errors due to nasalization, weak production of oral consonants was greater followed by nasalization of oral consonants, nasal fricatives and substitution of oral for nasal sounds. In VPD, the air pressure during the production of oral sounds is reduced because of the air escape through the nasal cavity due to inadequate velopharyngeal closure. This results in weak production of pressure consonants and in the current study the words selected for articulatory analysis were loaded with pressure consonants. So the frequency of weak production of oral consonants was high compared to other errors. However studies in the literature suggest that these nasalization errors can be continued after surgery in individuals with VPD even after the establishment of adequate velopharyngeal closure (Bzoch & Kenneth, 1964; Peterson-Falzone et al., 2001). The nasal fricatives are predominantly used in substitution of alveolar and palatal fricatives (Peterson-Falzone et al., 2006). The substitution of nasal for oral sounds by habit suggests the close relationship between articulation errors and hypernasality (Van Hatum, 1954).

On comparing the types of surgery, reduced compensatory articulation errors were seen in pharyngoplasty group followed by combined and palatoplasty group. The palatoplasty group showed significant difference between three conditions for overall articulation errors, substitutions and distortions. The pharyngoplasty group showed significant difference between pre and first follow-up conditions only. These results were in agreement with the previous studies mentioned in the literature (Karling et al., 1999; Tonz et al., 2002; Meek et al., 2003; Van Lierde et al., 2008). These studies investigated the speech outcomes following pharyngoplasty and they found improvement in articulation proficiency at different follow ups (4 months, 6 months and 1 year).

The other factor that contributes to the improvement in the articulation proficiency was timing or the age of the secondary surgery. The earlier studies have found the evidence of better the velopharyngeal closure higher the articulation proficiency (Dorf & Curtin, 1982; Grobbelaar et al., 1995). In this study the age range of subjects who underwent palatoplasty (FDOZ) was very less than that of the pharyngoplasty and combined surgery group. Thus surgical intervention at the younger age resulted in significant reduction in the compensatory articulation errors. This could be the contributing factor for better articulation outcomes in individuals who underwent FDOZ than pharyngoplasty group. These results were in consonance with the previous articulation outcome studies in individuals with VPD (Tonz et al., 2002; Meek et al., 2003; Van Lierde et al., 2008). Carlisle, Skyes and Singhal (2011) reported that both FDOZ and Pharyngoplasty are effective surgical procedures for better speech outcomes. In their retrospective study they consider 46 subjects in the same age range. But in the present study the age of secondary surgery was different for both the groups which further created difference in the articulation outcomes of individuals with VPD.

In the present study compensatory articulation errors decreased subsequent to surgery. After the surgical management of VPD, some individuals exhibited articulation errors as these atypical articulatory placements remain in the phonetic repertoire and occur in individuals with adequate velopharyngeal closure. Hence, speech therapy is essential in treating compensatory articulatory errors in individuals with VPD. Speech therapy is considered more effective after surgical management of VPD (Van Denmark & Hadin, 1986; Grunwell & Dive, 1988, Pamplona et al., 2004).

The study also indicated improvement in articulation from first to second follow up after attending speech therapy. In the present study, subjects for second follow up conditions were considered after minimum of 15 sessions of speech therapy. The speech therapy goals were focussed to improve oral breath stream, teaching place of articulation, and improving speech intelligiblity by reducing rate of speech and use of open mouth approach. The results showed significant reduction in errors following speech intervention. This suggests that there was an improvement in the velopharyngeal closure as this has direct influence on articulation proficiency. These results imply the effectiveness of speech therapy in reducing the articulation errors that is persistent after structural correction of velopharyngeal inadequacy. These results suggest that the speech intervention for correcting the compensatory articulatory errors requires a longer period (Kummer, 2001; Pamplona et al., 2012).

Pamplona et al. (2012) studied the effectiveness of speech therapy strategies for correcting articulation errors in individual with VPD. The authors evaluated 52 participants in the age range of 4 to 10 years with a mean age of 5 years and the inclusion criteria was the persistent compensatory articulation after secondary palatal repair. The speech therapy sessions consisted of 4 hours per day for a period of four weeks in a year and the techniques used in the intervention were modelling, cloze procedure with phonemic cues, phonetic changes and think aloud in phonemic awareness. The results showed significant relationship with the effectives of the speech intervention strategies and degree of severity of compensatory articulatory errors. The authors concluded that considering the speech intervention methods based on severity of the errors could help in improving the speech outcomes following speech intervention. In the present study, the improvement noticed in the articulation skills of six months follow-up group represents the importance of speech therapy following surgical management of velopharyngeal dysfunction.

4.2 Effect of surgery on resonance characteristics of Individuals with VPD

The results of resonance characteristics of individuals with VPD are described based on the type of assessment method used. The results are sub grouped into instrumental and perceptual methods of assessment of resonance characteristics. The instrumental evaluation of resonance in individuals with VPD was done through Nasometer and Cineradiographic assessment of velopharyngeal closure and subjected to different statistical analysis (Fig.10).

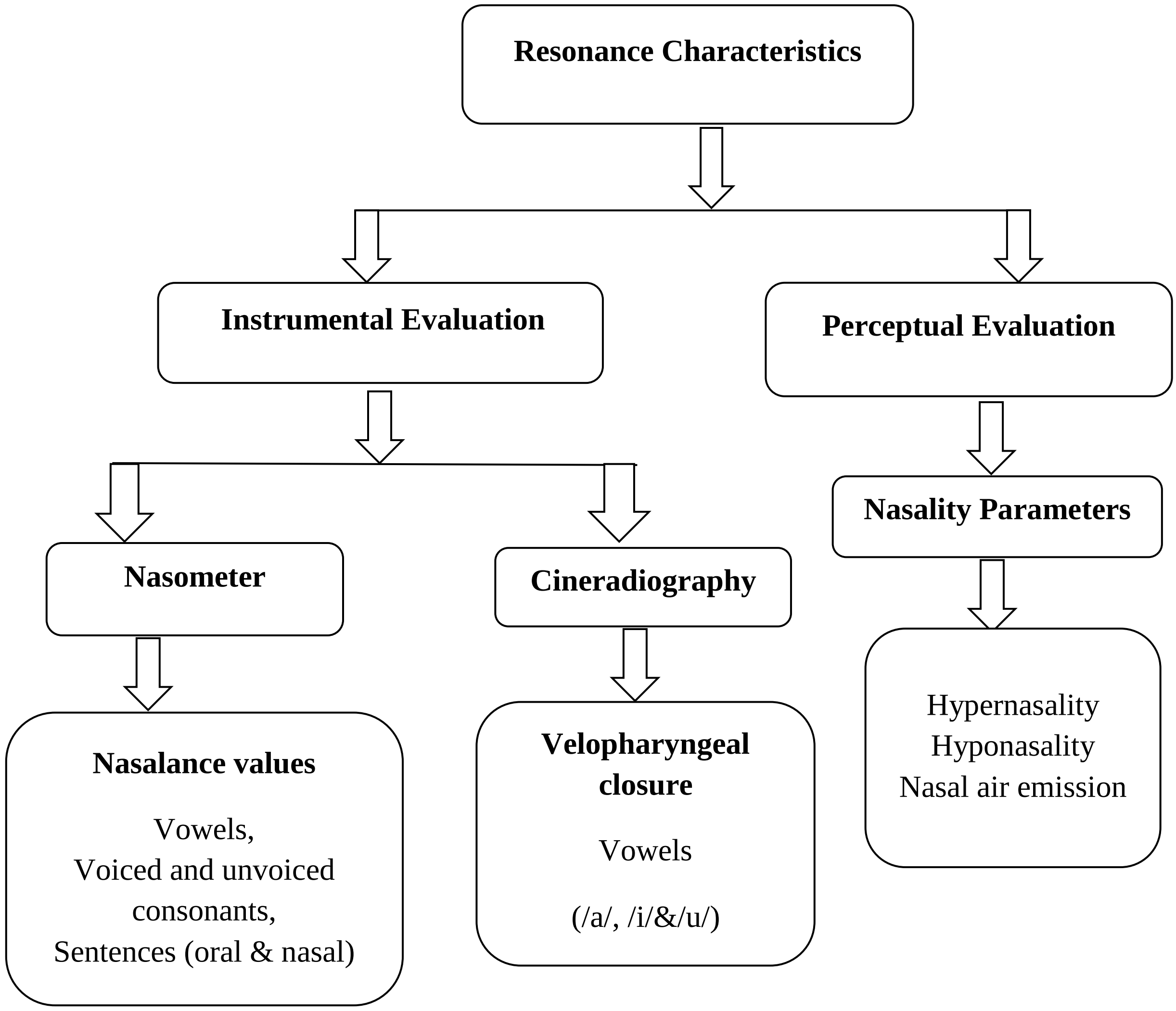


Figure 10. . Flow chart for summarizing analysis of resonance characteristics

4.2.1 Instrumental Assessment of Resonance Characteristics across Conditions

The nasalance values were obtained for vowels, voiced, unvoiced CV syllables and standardized sentences across age, gender and conditions. The obtained values were grouped across gender, age and conditions (Figure 11). Mann-Whitney U test was done to investigate any significant difference for nasalance values across gender. Females had higher nasalance values compared to male participants. The results showed that there was no significant difference ($p>0.05$) between males and females for nasalance values in individuals with VPD. The similar results were obtained across age (children Vs adults) on Mann-Whitney U test. Hence, the subjects were not grouped based on age and gender

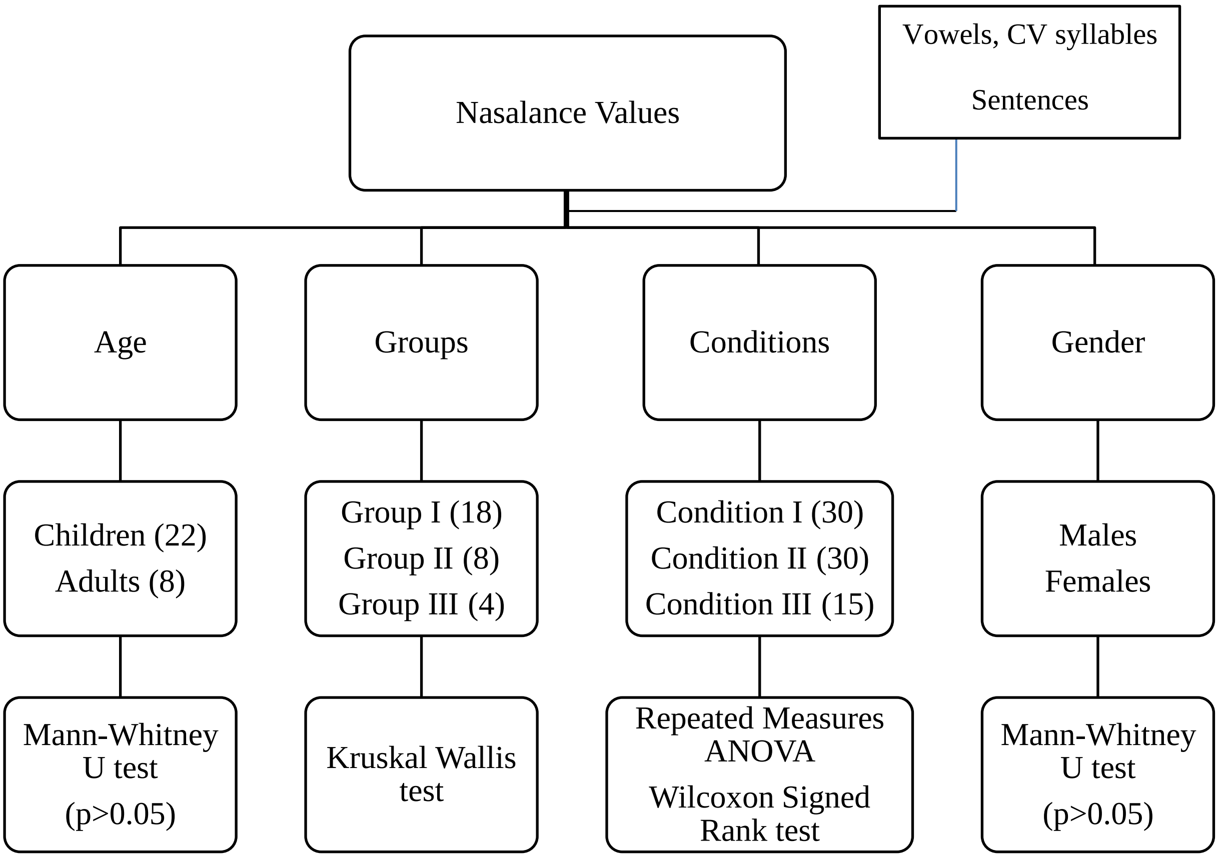


Figure 11. Flow chart for summarizing analysis of nasometric assessment.

4.2.1.1 Nasalance values of vowels

The mean, standard deviation and median for nasalance values of vowels across groups and conditions are depicted for children (Table 14) and adults (Table 15). Among children, nasalance value decreased for Condition II (3months follow up) and III (6 months follow up) compared to condition I (pre surgery) across types of groups and vowels. Among vowels, high vowel /i/ had higher mean nasalance values followed by back vowel /u/ and mid vowel /a/ across three conditions. Children had reduced nasalance values compared to adults. Similar trend was also seen for adults.

Table 14

Mean, Standard Deviation and Median for Nasalance Values (%) of Vowels in Children

Vowels	Type of Surgery	Nasalance values (%)											
		Condition I				Condition II				Condition III			
		N	***M***	***SD***	***Mdn***	N	***M***	***SD***	***Mdn***	N	***M***	***SD***	***Mdn***
/a/	G I	17	35.64	14.75	30.00	17	27.58	8.40	27.00	9	28.77	6.01	27.00
	G II	3	50.66	16.92	55.00	3	28.00	3.46	30.00	2	30.00	2.82	30.00
	G III	2	30.50	4.94	30.50	2	37.00	19.79	37.00	1	27.00*	-	27.00
	Total	22	37.22	15.04	33.00	22	28.50	9.01	27.50	12	28.83	5.25	27.00
/i/	G I	17	70.64	13.05	75.00	17	60.35	12.35	65.00	9	66.77	16.49	73.00
	G II	3	74.33	4.04	75.00	3	60.33	6.80	58.00	2	49.00	26.87	49.00
	G III	2	80.00	4.24	80.00	2	82.50	6.36	82.50	1	70.00*	-	70.00
	Total	22	72.00	11.86	75.00	22	62.36	12.85	65.00	12	64.08	17.72	69.00
/u/	G I	17	55.64	10.93	56.00	17	44.41	8.71	45.00	9	50.44	10.92	52.00
	G II	3	58.00	8.88	55.00	3	48.00	3.46	50.00	2	46.00	8.48	46.00
	G III	2	62.50	14.84	62.50	2	61.00	14.14	61.00	1	67.00*	-	67.00
	Total	22	56.59	10.64	55.50	22	46.40	9.60	47.00	12	51.08	11.01	52.00

Note. [M= Mean , SD = standard deviation , Mdn = Median ,Group I(GI) = Palatoplasty, Group II(GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I(CI) = Pre surgery, Condition II (CII) = 3months follow up, Condition III (CIII) = 6 months follow up , N = no. of subjects, * = Single subject's data, - = No standard deviation]

Table 15

Mean , Standard Deviation and Median for Nasalance Values (%) of Vowels in Adults

Vowels	**Type of Surgery**	**Nasalance values (%)**											
		Condition I				**Condition II**				**Condition III**			
		N	***M***	***SD***	***Mdn***	***N***	***M***	***SD***	***Mdn***	**N**	***M***	***SD***	***Mdn***
/a/	G I	1	48.00*	-	48.00	1	31.00*	-	31.00	1	35.00*	-	35.00
	G II	5	41.60	12.34	37.00	5	30.00	10.55	27.00	2	32.00	8.48	32.00
	G III	2	25.00	7.07	25.00	2	21.50	4.94	21.50	-	-	-	-
	Total	8	38.25	12.88	35.00	8	28.00	9.13	27.00	3	33.00	6.24	35.00
/i/	G I	1	78.00*	-	78.00	1	75.00*	-	75.00	1	50.00*	-	50.00
	G II	5	77.40	16.83	81.00	5	73.40	12.81	68.00	2	70.50	17.67	70.50
	G III	2	62.00	16.97	62.00	2	55.00	21.21	55.00	-	-	-	-
	Total	8	72.43	12.80	75.50	8	64.13	13.59	65.00	3	64.00	17.00	68.00
/u/	G I	1	63.00*	-	63.00	1	55.00*	-	55.00	1	48.00*	-	48.00
	G II	5	48.00	3.46	50.00	5	48.00	3.46	50.00	2	46.00	8.48	46.00
	G III	2	48.50	13.43	48.50	2	40.00	7.07	40.00	-	-	-	-
	Total	8	57.25	12.18	58.00	8	47.12	14.27	45.00	3	44.66	13.31	48.00

Note. [M= Mean, SD = standard deviation, Mdn = Median, Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3months follow up, Condition III (CIII) = 6 months follow up, N = no. of subjects, * = Single subject's data, - = No data / No Standard deviation]

4.2.1.1.1 Comparison across age (Children vs Adults)

Mann –Whitney U test was done to find whether significant difference was seen between adults and children on nasalance values of vowels (Table 16).

Table 16.

Results of Mann-Whitney U Test for vowels across Age

Vowels	**Conditions**		
	C I	**C II**	**C IIII**
	|z|	**|z|**	**|z|**
/a/	0.44	1.30	0.94
/i/	0.75	1.22	0.29
/u/	0.07	0.42	0.71

Note. P >0.05 [Condition I (CI) = Pre surgery, Condition II (CII) = 3months follow up, Condition III (CIII) = 6 months follow up]

The results showed that there was no significant difference between children and adults on nasalance values of vowels across conditions. As the nasalance values of vowels did not differ across children and adults, the subjects were considered as one group for further analysis.

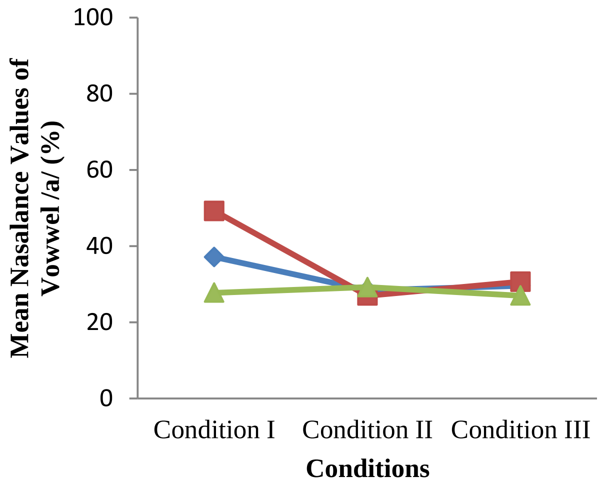
4.2.1.1.2 Comparison across groups

Kruskal Wallis test was done to investigate significant difference between groups (types of surgery) on nasalance values of vowels for condition I and II. The results showed that there was no significant difference between groups on nasalance values of vowels (/a/, /i/, /u/) across conditions [C I /a/ χ^2 (2) = 5.01, p > 0.05; C II /a/ χ^2 (2) = 0.443, p > 0.05; C I /i/ χ^2 (2)= 1.18, p > 0.05; C II /i/ χ^2 (2,)= 2.23, p > 0.05; C I /u/ χ^2 (2)= 0.14, p > 0.05; C II /u/ χ^2 (2) = 0.21, p > 0.05].

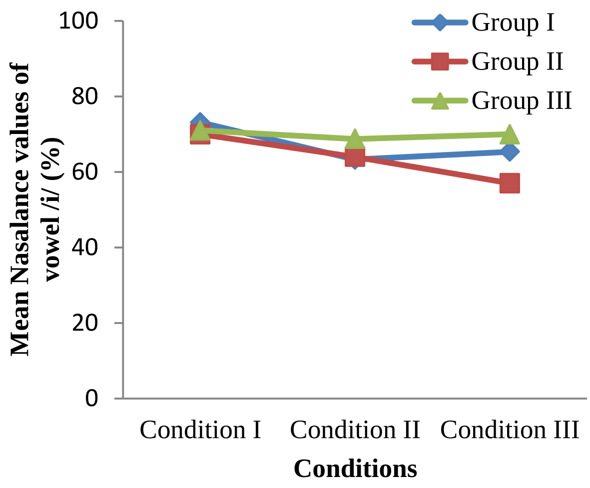
Mann-Whitney test was done to find significant difference across groups I and II for condition III of vowels (/a/, /i/and /u/). The test results indicated that there was no significant deference between groups I and II for condition III of vowel /a/ [G I – G II (|z| = 0.64, p > 0.05)], /i/ [G I – G II (|z| = 0.42, p > 0.05)] and /u/ [G I – G II (|z| = 0.50, p > 0.05)]. Kruskal Wallis test could not be carried out because condition III of group III had only one subject data. The data showed that condition III nasalance values of group III was higher for /i/ and /u/ compared to condition III scores of other two groups.

4.2.1.1.3 Comparison across conditions

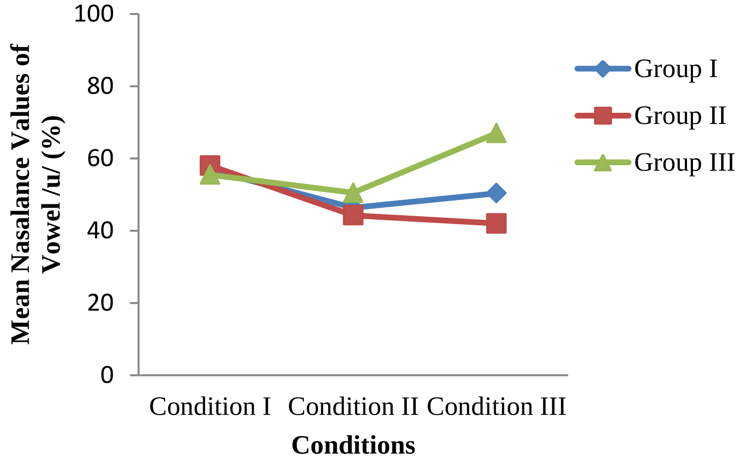
Nasalance values were compared across condition for each group. Among the types of surgery, group I (palatoplasty) followed normal distribution so repeated measures ANOVA was done to find any significant main effect on conditions for nasalance values of vowels. The results revealed that significant main effect on conditions for vowel /a/ [F (2, 18) = 8.01, P < 0.01; effect size (η_p^2= 0.93)] and vowel /u/ [F (2, 18) = 5.01, P < 0.05; effect size (η_p^2= 0.97)]. There was no significant interaction effect seen across conditions for vowel /i/ [F (2, 18) =2.98, P > 0.05, effect size (η_p^2= 0.98)]. Post hoc test using Bonferroni correction was done for nasalance values of vowel /a/ and /u/. The results revealed that there was significant difference (p < 0.05) between all the three conditions for vowel /a/. However, no significant difference (p > 0.05) was observed across conditions for vowel /u/.



(i)



(ii)



(iii)

[Group I (GI) - Palatoplasty, Group II (GII) –Pharyngoplasty, Group III (GIII) - Combined Surgery, Condition I (CI) – Pre surgery, Condition II (CII) – 3months follow up, Condition III (CIII) – 6 months follow up]

Figure 12. Types of surgery on nasalance values of vowels (i-/a/, ii-/i/ and iii -/u/) across conditions.

Figure 12 depicts the mean nasalance values for vowels (/a/, /i/ and /u/) across groups and conditions. The mean values were greater for vowel /i/ followed by vowel/u/ and /a/. Wilcoxon's signed rank test was done for group II (pharyngoplasty) and group III (combined surgery) to explore any significant difference across conditions for vowels (/a/, /i/, /u/) (Table 17).

Table 17

Results of Wilcoxon's signed Rank Test for Vowels across conditions

Conditions		Types of Surgery	
		G II	G III
		|z|	|z|
C I-C II	/a/	2.52**	0.36
	/i/	1.18	0.55
	/u/	2.22**	0.73
C I- C III	/a/	1.06	-
	/i/	0.73	-
	/u/	0.73	-
C II- C III	/a/	1.46	-
	/i/	1.06	-
	/u/	1.00	-

Note. ** $P < 0.01$ [Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up]

The results showed significant difference (p<0.01) between condition I and II for vowels /a/ and /u/ for group II. No difference was seen for condition III. For group III (combined surgery), there was no significant difference between nasalance values of condition I and II of all the three vowels. Friedman test could not be done to find overall difference because of fewer subjects in condition III for the groups II and III. The data showed that for group I condition III had higher nasalance values for all the vowels but group I had reduced nasalance scores in Condition III. Group III had no subjects in Condition III for nasalance values of vowels.

4.2.1.2 Nasalance values of unvoiced CV syllables

The mean, standard deviation and median for nasalance values of unvoiced pressure consonants (/p/, /t/, /k/) across groups and conditions are depicted for children (Table 18) and adults (Table 19). The nasalance values decreased for unvoiced CV syllables in conditions II (3 months follow up) and III (6 months follow up) compared to condition I (pre surgery) across groups. The overall mean values for palatal voiceless consonant /t/ had higher nasalance values followed by bilabial /p/ and velar /k/ in the context of vowel /a/ across three conditions. Children had reduced nasalance values compared to adults. Similar trend was also seen for adults.

Table 18

Mean, Standard Deviation and Median for Nasalance Values (%) of unvoiced CV Syllables in Children.

CV Syllables	Type of Surgery	Nasalance values (%)											
		Condition I				Condition II				Condition III			
		N	***M***	***SD***	***Mdn***	N	***M***	***SD***	***Mdn***	N	***M***	***SD***	***Mdn***
/pa/	G I	17	43.88	12.44	38.00	17	33.23	10.93	30.00	9	32.33	8.09	28.00
	G II	3	47.00	3.60	48.00	3	35.66	5.13	37.00	2	31.00	5.65	31.00
	G III	2	48.50	33.23	48.50	2	34.00	12.72	34.00	1	29.00*	-	29.00
	Total	22	44.72	13.20	44.00	22	33.63	10.10	30.00	12	31.83	7.18	28.50
/ta/	G I	17	45.70	14.67	43.00	17	38.70	13.40	38.00	9	35.44	11.45	35.00
	G II	3	55.66	14.29	59.00	3	41.00	3.60	40.00	2	31.50	9.19	31.50
	G III	2	47.50	34.64	47.50	2	32.00	9.89	32.00	1	40.00*	-	40.00
	Total	22	47.22	15.89	44.50	22	38.40	12.15	38.50	12	35.16	10.38	35.50
/ka/	G I	17	44.23	13.96	44.00	17	35.23	9.04	35.00	9	33.00	8.91	36.00
	G II	3	44.33	10.96	48.00	3	33.33	5.13	32.00	2	29.00	1.41	29.00
	G III	2	33.50	12.02	33.50	2	31.50	12.02	31.50	1	28.00*	-	28.00
	Total	22	43.27	13.29	43.00	22	34.63	8.55	34.50	12	31.91	7.86	34.00

Note. [M= Mean, SD = Standard deviation, Mdn = Median, Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, * = Single subject's data, - = No standard deviation]

Table 19

Mean, Standard Deviation and Median for Nasalance Values (%) of unvoiced CV Syllables in Adults

CV Syllables	Type of Surgery	Nasalance values (%)											
		Condition I				Condition II				Condition III			
		N	***M***	***SD***	***Mdn***	N	***M***	***SD***	***Mdn***	N	***M***	***SD***	***Mdn***
/pa/	G I	1	47.00*	-	47.00	1	28.00*	-	28.00	1	33.00*	-	33.00
	G II	5	51.00	16.14	43.00	5	30.00	12.06	27.00	2	31.00	9.89	31.00
	G III	2	29.50	14.8	29.50	2	24.00	5.65	24.00	-	-	-	-
	Total	8	45.12	16.59	42.50	8	28.25	9.75	27.50	3	31.66	7.09	33.00
/ta/	G I	1	44.00*	-	44.00	1	27.00*	-	27.00	1	30.00*	-	30.00
	G II	5	53.40	15.77	52.00	5	39.40	11.52	39.00	2	36.00	15.55	36.00
	G III	2	27.00	12.72	27.00	2	23.50	6.36	23.50	-	-	-	-
	Total	8	45.62	17.54	47.00	8	33.87	11.87	28.00	3	34.00	11.53	30.00
/ka/	G I	1	37.00*	-	37.00	1	30.00*	-	30.00	1	33.00*	-	33.00
	G II	5	48.60	14.79	48.00	5	38.00	12.18	32.00	2	36.00	18.38	36.00
	G III	2	25.50	4.94	25.50	2	21.50	0.70	21.50	-	-	-	-
	Total	8	41.37	15.50	35.50	8	32.80	11.90	30.50	3	35.00	13.11	33.00

Note. [M= Mean, SD = Standard deviation, Mdn = Median, Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, N= no. of subjects, * = Single subject's data, - = No data / No Standard deviation]

The results observed for unvoiced consonants (/p/, /t/, /k/) in the context of vowels /i/ and /u/ were different (Appendix E) compared to nasalance values of unvoiced consonant in the context of vowel /a/. Nasalance values were higher for unvoiced consonants followed by vowels /i/ than vowels /u/ and /a/. Adult subjects had greater nasalance values compared to children.

4.2.1.2.1 Comparison across age (Children vs Adults)

Mann –Whitney U test was done to find whether significant difference was seen between adults and children on nasalance values of unvoiced CV syllables. The results showed that there was no significant difference between children and adults on nasalance values of unvoiced CV syllables across conditions.

Table 20

Results of Mann-Whitney U Test for unvoiced CV syllables across Age

Unvoiced CV Syllables	**Conditions**		
	C I	**C II**	**C IIII**
	|z|	**|z|**	**|z|**
/pa/	0.07	1.50	0.00
/ta/	0.21	1.05	0.50
/ka/	0.25	0.77	0.07
/pi/	1.24	0.42	0.26
/ti/	1.17	0.96	0.28
/ki/	0.72	0.37	0.21
/pu/	0.18	1.40	0.65
/tu/	0.70	0.28	1.23
/ku/	1.15	1.03	1.01

Note. $p > 0.05$ [Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up]

As the nasalance values of unvoiced CV syllables did not differ significantly ($p > 0.05$) across children and adults they were considered as one predominant group.

4.2.1.2.2 Comparison across groups

Kruskal Wallis test was done to investigate significant difference across groups (types of surgery) on nasalance values of unvoiced CV syllables for conditions I and II in individuals with VPD (Table 21).

Table 21

Results of Kruskal Wallis Test for unvoiced Consonants across groups

unvoiced consonants	**Conditions**	
	C I	**C II**
	χ^2 **(df =2)**	χ^2 **(df=2)**
/pa/	2.03	0.65
/ta/	3.04	4.01
/ka/	2.72	3.04
/pi/	5.33	0.29
/ti/	2.22	1.72
/ki/	1.74	2.72
/pu/	0.29	0.43
/tu/	1.05	0.29
/ku/	1.29	1.07

Note. $p > 0.05$ [Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up]

The results showed that there was no significant difference between groups on nasalance values of unvoiced CV syllables across conditions I and II. Mann-Whitney test was done to find significant difference across groups I and II for condition III of unvoiced CV syllables (Table 22).

Table 22

Results of Mann-Whitney U Test for unvoiced CV syllables across groups I and II

Unvoiced CV Syllables	**Conditions**
	C III
	|z|
/pa/	0.28
/ta/	0.28
/ka/	0.70
/pi/	0.28
/ti/	0.70
/ki/	0.70
/pu/	0.56
/tu/	1.49
/ku/	0.28

Note. $p > 0.05$ [Condition III (CIII) = 6 months follow up]

The test results indicated that there was no significant difference between groups I and II for condition III of unvoiced CV syllables. Kruskal Wallis test could not be carried out because condition III of group III had fewer subjects. The data showed that condition III nasalance values of group III was higher for /ta/ compared to condition III scores of other two groups.

4.2.1.2.3 Comparison across conditions

Among the types of surgery, group I (palatoplasty) followed a normal distribution. To compare the nasalance values of unvoiced CV syllables (/p/, /t/ and /k/) in the context of vowels (/a/, /i/ and /u/) across conditions repeated measures ANOVA was carried out for group I (Table 23). The results depicted significant main effect (p <0.05) for conditions on nasalance values of unvoiced consonants (/pa/, /ta/, /ka/, /pi/, /ti/, /pu/) and not for (/ki/, /tu/ and /ku/). Post hoc tests using Bonferroni correction was done for those unvoiced consonants which had overall significant difference across conditions.

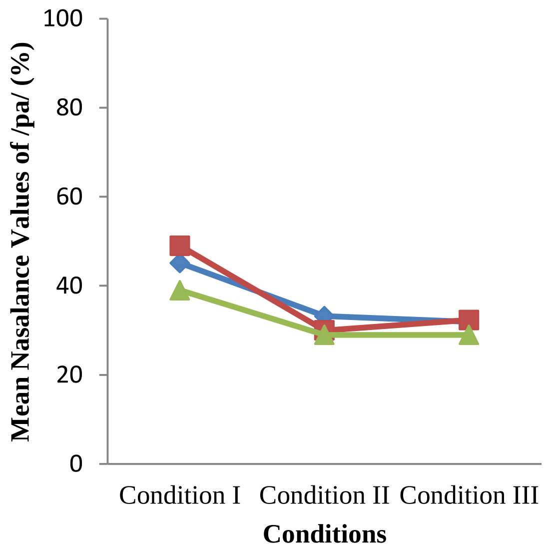
Table 23

Results of Repeated Measure ANOVA for unvoiced Consonants of Group I

CV Syllables	**Conditions**	
	F Value (2,18)	**ES (η_p^2)**
/pa/	6.05*	0.99
/ta/	3.51*	0.96
/ka/	5.47*	0.99
/pi/	5.42*	0.97
/ti/	6.79*	0.97
/ki/	2.17	0.99
/pu/	4.69*	0.98
/tu/	2.66	0.96
/ku/	2.40	0.99

Note. **P<0.01 * P < 0.05 [ES = Effect Size]

The results showed significant difference (p<0.05) between Condition I and II for unvoiced consonant /pu/. For unvoiced consonant /ti/ significant difference (p<0.05) between Condition I and III was observed. For all other unvoiced consonants significant difference between the conditions was not observed.



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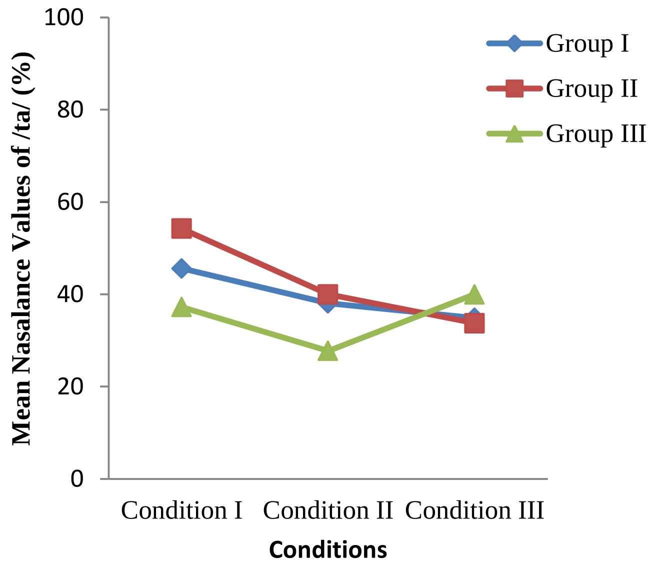

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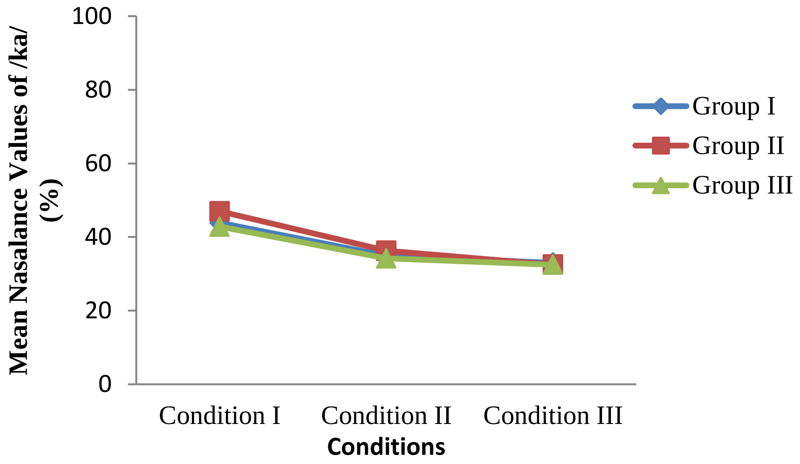


(c)

[Group I (GI) - Palatoplasty, Group II (GII) –Pharyngoplasty, Group III (GIII) - Combined Surgery, Condition I (CI) – Pre surgery, Condition II (CII) – 3 months follow up, Condition III (CIII) – 6 months follow up]

Figure 13. Types of surgery on nasalance values of unvoiced consonants (a -/pa/, b-/ta/, c-/ka/) across conditions

The Figure 13 represents the effects of different types of surgery on nasalance of unvoiced pressure consonants (/p/, /t/, /k/) in the context of vowel /a. Wilcoxon's signed rank test was done for group II (pharyngoplasty) and III (combined surgery) to investigate significant difference across conditions for unvoiced consonants (/p/, /t/, /k/) in the context of vowels (/a/, /i/, /u/) which is depicted in Table 24.

Table 24

Results of Wilcoxon's Signed Rank Test for unvoiced Consonants across conditions.

CV Syllables	**C I – C II Surgery**		**C I –C III Surgery**		**C II – C III Surgery**	
	G II	**G III**	**G II**	**G III**	**G II**	**G III**
	|z|	**|z|**	**|z|**	**|z|**	**|z|**	**|z|**
/pa/	2.52**	0.36	1.86	-	1.84	-
/ta/	2.52**	0.36	1.82	-	0.73	-
/ka/	2.52**	0.73	1.09	-	0.36	-
/pi/	2.83**	0.73	1.86	-	0.00	-
/ti/	2.52**	0.36	1.86	-	0.73	-
/ki/	2.52**	0.36	1.06	-	0.73	-
/pu/	2.52**	0.73	1.46	-	0.73	-
/tu/	1.85	0.73	1.28	-	1.85	-
/ku/	2.52**	0.36	1.46	-	0.36	-

Note. **P<0.01 * P < 0.05 [Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up]

The results showed significant difference between condition I and II for all the unvoiced pressure consonants of group II (pharyngoplasty) except for unvoiced consonant /tu/. In group III (combined surgery), significant difference was not observed between condition I and II on nasalance values of all the unvoiced consonants. Friedman test could not be done because condition III (6 months follow up) of group III had less than three subjects. The mean scores depicts that the mean nasalance values of children had reduced nasalance values in condition III in the bilabial and velar unvoiced consonants than condition I and II in group III. The palatal unvoiced consonanat had greater nasalance values compared to condition II of group III and similar trend was noticed in all three vowel context.

4.2.1.3 Nasalance values of voiced CV syllables

The mean, standard deviation and median for nasalance values of voiced pressure consonants (/b/, /d/, /g/) across groups and conditions are depicted for children (Table 25) and adults (Table 26). The nasalance values decreased for voiced CV syllables condition II (3 months follow up) and III (6 months follow up) compared to condition I (pre surgery) across types of surgery. The results showed that the overall mean value for velar voiced consonant /g/ had higher nasalance values followed by palatal /d/ and bilabial /b/ in the context of vowel /a/ across three conditions. Children had reduced nasalance values compared to adults. Similar trend was also seen for adults. Voiced CV syllables had higher nasalance values compared to unvoiced CV syllables.

Table 25

Mean , Standard Deviation and Median for Nasalance Values (%) of Voiced CV syllables in children

CV Syllables	Type of Surgery	Nasalance values (%)											
		Condition I				Condition II				Condition III			
		N	*M*	*SD*	*Mdn*	*N*	*M*	*SD*	*Mdn*	N	*M*	*SD*	*Mdn*
/ba/	G I	17	52.41	12.36	58.00	17	43.17	10.39	41.00	9	43.44	16.43	50.00
	G II	3	50.66	3.05	50.00	3	37.33	10.01	38.00	2	32.50	3.53	32.50
	G III	2	27.00	8.48	27.00	2	32.00	1.41	32.00	1	43.00*	-	43.00
	Total	22	49.86	13.26	51.00	22	41.36	10.26	40.50	12	41.58	14.68	45.00
/da/	G I	17	52.64	10.65	53.00	17	43.76	7.33	44.00	9	39.88	11.81	45.00
	G II	3	52.00	2.64	51.00	3	48.00	2.64	49.00	2	44.00	1.41	44.00
	G III	2	31.00	9.89	31.00	2	34.00	1.41	34.00	1	48.00*	-	48.00
	Total	22	50.59	11.49	51.00	22	43.45	7.30	44.50	12	41.25	10.42	45.00
/ga/	G I	17	51.47	14.00	52.00	17	43.00	13.49	44.00	9	45.55	13.37	45.00
	G II	3	54.33	8.50	54.00	3	46.00	16.37	50.00	2	41.50	9.19	41.50
	G III	2	41.50	14.84	41.50	2	34.50	3.53	34.50	1	74.00*	-	74.00
	Total	22	50.95	13.31	52.00	22	42.63	13.14	43.00	12	47.25	14.52	46.50

Note. [M= Mean, SD = standard deviation, Mdn = Median, Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I(CI) = Pre surgery, Condition II (CII) = 3months follow up, Condition III (CIII) = 6 months follow up, , N = no. of subjects, * = Single subject's data, - = No Standard deviation]

Table 26

Mean, Standard Deviation and Median for Nasalance Values (%) of Voiced CV syllables in adults

CV Syllables	Type of Surgery	Nasalance values (%)											
			Condition I				Condition II				Condition III		
		N	*M*	*SD*	*Mdn*	N	*M*	*SD*	*Mdn*	N	*M*	*SD*	*Mdn*
/ba/	G I	1	51.00*	-	51.00	1	47.00*	-	47.00	1	40.00*	-	40.00
	G II	5	59.60	12.38	59.00	5	41.80	9.33	43.00	2	29.00	5.65	29.00
	G III	2	26.00	2.82	26.00	2	21.00	1.41	21.00	-	-	-	-
	Total	8	50.12	17.86	49.50	8	37.25	12.40	41.50	3	32.66	7.50	33.00
/da/	G I	1	47.00*	-	47.00	1	46.00*	-	46.00	1	40.00*	-	40.00
	G II	5	58.40	10.69	52.00	5	42.20	13.80	41.00	2	35.00	14.14	35.00
	G III	2	31.50	2.12	31.50	2	31.00	1.41	31.00	-	-	-	-
	Total	8	50.25	14.67	50.50	8	39.80	11.87	36.50	3	36.66	10.40	40.00
/ga/	G I	1	46.00*	-	46.00	1	46.00*	-	46.00	1	45.00*	-	45.00
	G II	5	59.00	5.65	62.00	5	42.60	8.20	44.00	2	36.00	8.48	36.00
	G III	2	41.50	3.53	41.50	2	37.50	10.60	37.50	-	-	-	-
	Total	8	53.00	9.51	53.00	8	41.75	7.92	44.50	3	39.00	7.93	42.00

Note. [M= Mean , SD = standard deviation , Mdn = Median , Group I(GI) = Palatoplasty, Group II(GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I(CI) = Pre surgery, Condition II (CII) = 3months follow up, Condition III (CIII) = 6 months follow up, N =no. of subjects, * = Single subject's data, - = No data / No Standard deviation]

The results noticed for voiced consonants (/b/, /d/, /g/) in the context of vowels /i/ and /u/ were different (Appendix E) to that of the nasalance values obtained for voiced consonants in the context of vowel /a/. The results showed higher nasalance values for voiced consonants in the context of vowels /i/ followed by vowel /u/ and /a/. Adult subjects had greater nasalance values compared to children.

4.2.1.3.1 Comparison across age (Children vs Adults)

Mann –Whitney U test was done to find whether significant difference was seen between adults and children on nasalance values of voiced CV Syllables (Table 27). The results showed that there was no significant difference between children and adults on nasalance values of Voiced CV syllables across conditions.

Table 27

Results of Mann-Whitney U Test for Voiced CV syllables across Age

CV Syllables	Conditions		
	C I	C II	C III
	|z|	|z|	|z|
/ba/	0.02	0.56	1.29
/da/	0.28	1.19	0.94
/ga/	0.02	0.09	0.93
/bi/	0.25	0.35	0.21
/di/	0.04	0.21	1.47
/gi/	1.24	0.49	1.37
/bu/	0.98	1.69	0.94
/du/	1.47	2.06	1.37
/gu/	0.82	0.16	0.07

Note. $p > 0.05$ [C I = Presurgery, C II = First follow up, C III = Second follow up]

As the nasalance values of voiced CV syllables did not differ significantly across children and adults they were considered as one predominant group.

4.2.1.3.2 Comparison across groups

Kruskal Wallis test was done to explore significant difference across groups on nasalance values of voiced CV syllables for conditions I and II (Table 28).

Table 28

Results of Kruskal Wallis Test for Voiced CV syllables across groups

CV Syllables	Conditions	
	C I	C II
	χ^2 (df =2)	χ^2 (df=2)
/ba/	9.50^{**}	7.10^{*}
/da/	9.37^{**}	5.83^{*}
/ga/	4.77	1.32
/bi/	0.59	0.86
/di/	2.37	1.25
/gi/	2.67	1.14
/bu/	2.33	1.88
/du/	4.26	1.51
/gu/	2.93	0.89

Note. $^{**}P<0.01$ $^{*}P < 0.05$ [C I = Presurgery, C II = First follow up]

The results showed that there was significant difference between condition II nasalance values of voiced pressure consonants /ba/ and /da/ across groups. Mann-Whitney U test was done to compare Condition II nasalance values of consonants /ba/

and /da/ to find across which groups the significant difference was seen. The results showed that for both /ba/ ($|z| = 2.55$, $p<0.01$) and /da/ ($|z| = 2.81$, $p<0.01$) significant difference was observed between all the groups.

Mann-Whitney test was done to find significant difference across groups I and II for condition III of voiced CV syllables (Table 29).

Table 29

Results of Mann-Whitney U Test for voiced CV syllables across groups

Unvoiced CV Syllables	**Conditions**
	C III
	|z|
/ba/	1.69
/da/	0.35
/ga/	0.99
/bi/	0.63
/di/	0.99
/gi/	0.42
/bu/	0.78
/du/	0.70
/gu/	0.64

Note. $p > 0.05$ [Condition III (CIII) = 6 months follow up]

The test results indicated that there was no significant difference between groups I and II for condition III of voiced CV syllables. Kruskal Wallis test could not be carried out because condition III of group III had fewer subjects. The data showed that condition III nasalance values of group III was higher for /ga/ compared to condition III scores of other two groups.

4.2.1.3.3 Comparison across conditions

Among the types of surgery, group I (palatoplasty) followed a normal distribution so a repeated measure ANOVA was done to determine statistically significant difference for nasalance values of voiced CV syllables across conditions. The results are represented in Table 30 which depicts main effects ($p < 0.05$) of conditions on nasalance values of all the voiced consonants (/ba/, /da/, /ga/, /bi/, /di/, /gi/, /bu/, /du/ and /gu/).

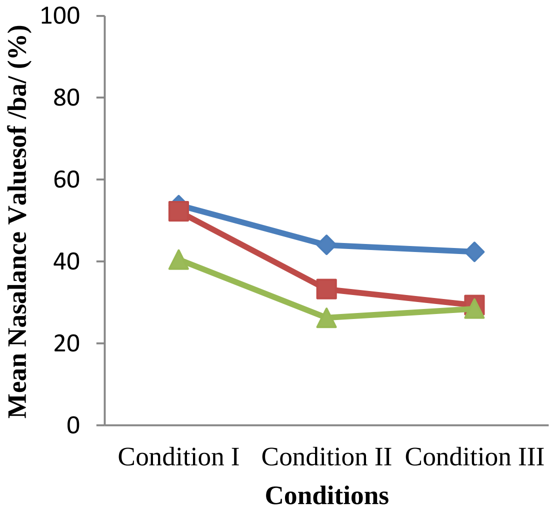
Table 30

Results of Repeated Measure ANOVA for Voiced Consonants of Palatoplasty Group

CV Syllables	Conditions	
	F Value (2,6)	**ES (η_p^2)**
/ba/	25.1**	0.98
/da/	4.70*	0.99
/ga/	11.5*	0.98
/bi/	6.47*	0.98
/di/	21.4*	0.97
/gi/	20.4*	0.99
/bu/	12.3*	0.97
/du/	7.56*	0.98
/gu/	6.41*	0.99

Note. **P<0.01 *P < 0.05 [ES = Effect size]

Post hoc tests using Bonferroni correction was done for all the voiced consonants across conditions. The results indicated that for voiced consonants (/ba/, /di/ and /gi/) significant difference (p<0.05) was observed between condition I and III. For voiced consonants /bu/ and /di/ there was a significant difference between condition I and III. For all other voiced consonants there was no significant difference between the conditions.



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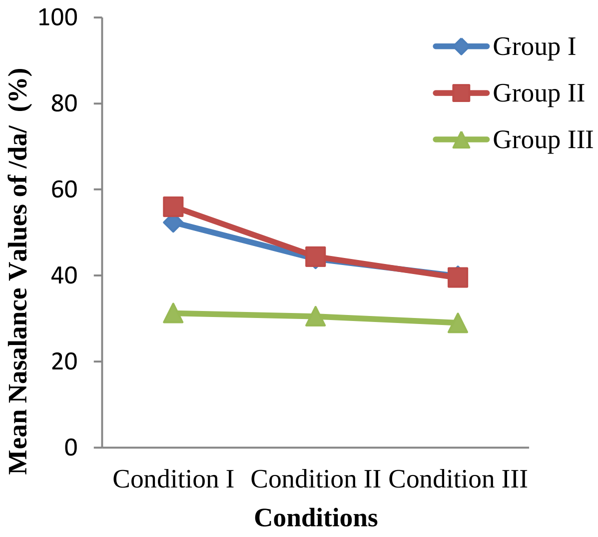

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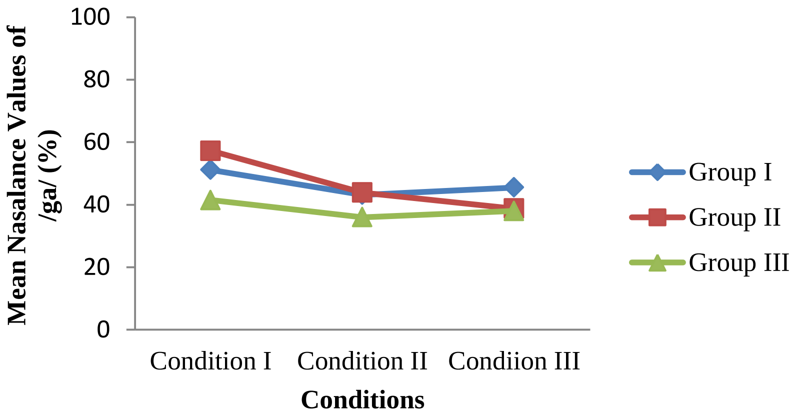


(c)

[Group I (GI) - Palatoplasty, Group II (GII) –Pharyngoplasty, Group III (GIII) - Combined Surgery, Condition I (CI) – Pre surgery, Condition II (CII) – 3months follow up, Condition III (CIII) – 6 months follow up]

Figure 14. Effect of types of surgery on nasalance values of voiced consonants (a-/ba/, b-/da/, c-/ga/) across conditions.

The Figure 14 shows the effects of different types of surgery on nasalance of voiced pressure consonants (/b/, /d/, /g/) in the context of vowel /a/. Wilcoxon's signed rank test was done for group II (pharyngoplasty) and group III (combined surgery) to explore significant difference between conditions for voiced pressure consonants (/b/, /d/, /g/) in the context of vowels (/a/, /i/, /u/) (Table 31).

Table 31

Results of Wilcoxon's Signed Rank Test for Voiced CV Syllables across conditions

Conditions	**C I – CII**		**C I –C III**		**C II- C III**	
Parameters	**Surgery**		**Surgery**		**Surgery**	
	G II	**G III**	**G II**	**GIII**	**GII**	**GIII**
	|z|	**|z|**	**|z|**	**|z|**	**|z|**	**|z|**
/ba/	2.52**	0.36	1.82	-	1.82	-
/da/	2.52**	0.36	1.82	-	1.28	-
/ga/	2.52**	0.73	1.82	-	0.36	-
/bi/	2.52**	0.73	1.82	-	1.60	-
/di/	2.38**	1.09	1.82	-	0.36	-
/gi/	2.52**	0.36	1.84	-	1.46	-
/bu/	2.52**	0.73	1.82	-	0.73	-
/du/	2.52**	1.09	1.28	-	1.85	-
/gu/	2.52**	1.46	1.60	-	0.55	-

Note. **$P<0.01$ * $P < 0.05$ [Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I(CI) = Pre surgery, Condition II (CII) = 3months follow up, Condition III (CIII) = 6 months follow up]

For group II (Pharyngoplasty), the results showed that there was a significant difference ($p < 0.05$) between condition I and condition II nasalance values of all voiced consonants considered. There was no significant difference ($p > 0.05$) seen for condition III when compared with condition I and condition III for all the voiced pressure consonants. For group III (combined surgery), Wilcoxon's signed rank test showed no significant difference ($p > 0.05$) between conditions I and II for voiced CV syllables. Friedman test could not be done to find overall difference because of fewer subjects in condition III for the groups II and III.

4.2.1.4 Nasalance values of sentences

The mean, standard deviation and median for nasalance values of oral and nasal sentences across groups and conditions are depicted for children (Table 32) and adults (Table 33). The nasalance values for sentences reduced from condition I (pre surgery) to condition II (3 months follow up) and III (6 months follow up) across groups**.** The overall mean values for nasal sentences were higher than oral sentences across conditions. Similar pattern of results were seen for adults. Children had reduced nasalance values compared to adults.

Table 32

Mean, Standard Deviation and Median for Nasalance Values of Sentences (oral and nasal) across Surgery in Children.

Stimuli	**Type of Surgery**	**Nasalance values (%)**											
		Condition I				**Condition II**				**Condition III**			
		N	***M***	***SD***	***Mdn***	***N***	***M***	***SD***	***Mdn***	**N**	***M***	***SD***	***Mdn***
OS	G I	17	50.95	8.65	52.12	17	44.45	6.16	43.7	9	44.25	10.55	46.00
	G II	3	53.62	11.12	55.00	3	43.33	16.07	50.00	2	43.93	1.32	43.93
	G III	2	49.50	13.43	49.50	2	45.50	7.77	45.50	1	46.75*	-	46.75
	Total	22	51.18	8.86	52.56	22	44.39	7.52	44.35	12	44.41	9.03	45.43
NS	G I	17	65.43	5.12	68.00	17	57.71	7.24	60.00	9	61.20	7.53	64.00
	G II	3	62.66	2.51	63.00	3	55.20	6.27	54.00	2	54.93	0.09	54.93
	G III	2	60.43	13.88	60.43	2	60.06	6.986	60.06	1	55.00*	-	55.00
	Total	22	64.60	5.70	66.05	22	57.58	6.89	59.18	12	59.64	7.02	59.93

Note. [M= Mean , SD = standard deviation , Mdn = Median , Group I(GI) = Palatoplasty, Group II(GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, , OS = Oral Sentences , NS = Nasal sentences , N = no. of subjects, * = Single subject's data, - = No standard deviation]

Table 33

Mean, Standard Deviation and Median for Nasalance Values of Sentences (oral and nasal) across Surgery in adults.

Age	Type of Surgery	Nasalance values (%)											
		Condition I				Condition II				Condition III			
		N	*M*	*SD*	*Mdn*	N	*M*	*SD*	*Mdn*	N	*M*	*SD*	*Mdn*
OS	G I	1	54.75*	-	54.75	1	40.62*	-	40.62	1	38.00*	-	38.00
	G II	5	56.79	12.77	50.54	5	48.32	13.45	41.80	2	41.81	2.55	41.81
	G III	2	45.50	3.53	45.50	2	39.06	1.49	39.06	-	-	-	-
	Total	8	53.71	11.00	50.27	8	45.04	11.15	40.47	3	40.54	2.84	40.00
NS	G I	1	70.18*	-	70.18	1	58.62*	-	58.62	1	59.00*	-	59.00
	G II	5	69.07	9.15	71.80	5	61.38	11.77	63.60	2	56.50	4.94	56.50
	G III	2	62.00	14.14	62.00	2	54.31	0.97	54.31	-	-	-	-
	Total	8	67.44	9.37	70.99	8	59.26	9.47	57.68	3	57.33	3.78	59.00

Note. [M= Mean, SD = standard deviation, Mdn = Median, Group I (GI) = Palatoplasty, Group II(GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I(CI) = Pre surgery, Condition II (CII) = 3months follow up, Condition III (CIII) = 6 months follow up, OS = Oral Sentences , NS = Nasal sentences, * = Single subject's data, - = No data / No Standard deviation]

4.2.1.4.1 Comparison across age (Children vs Adults)

Mann –Whitney U test was done to find whether significant difference was seen between adults and children on nasalance values of sentences. The results showed that there was no significant difference between children and adults on nasalance values of oral sentences [C I OS ($|z| = 0.07$, $P > 0.05$); C II OS ($|z| = 0.44$, $P > 0.05$); C III OS ($|z| = 1.44$, $P > 0.05$); C I NS ($|z| = 1.36$, $P > 0.05$); C II NS ($|z| = 0.30$, $P > 0.05$); C III NS ($|z| = 0.72$, $P > 0.05$)]. As the nasalance values of sentences did not differ across children and adults they were considered as one predominant group.

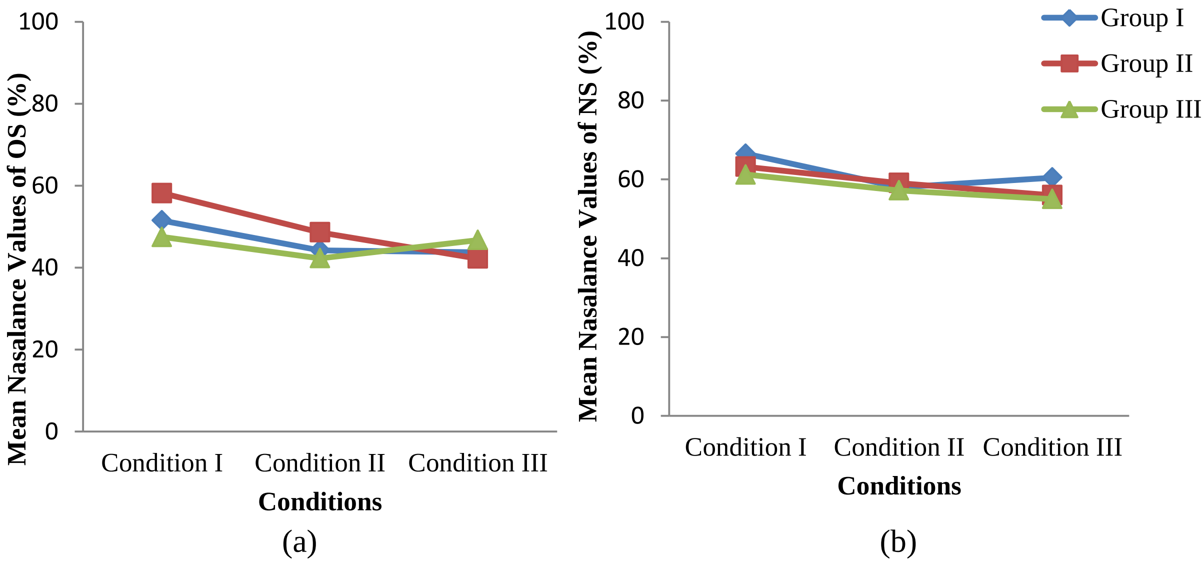
4.2.1.4.2 Comparison across groups

Kruskal Wallis test was done to investigate whether significant difference on across groups for nasalance values of oral and nasal sentences for condition I and II. The results showed no significant difference for types of surgery on nasalance values of oral sentences [C I OS χ^2 (2, N=30)= 1.99, $p > 0.05$; C II OS χ^2 (2, N=30)= 0.82, $p > 0.05$] and nasal sentences [C I NS χ^2 (2, N=30) = 0.15, $p > 0.05$) ; C IINS χ^2 (2, N=30) = 0.03, $p > 0.05$].

Mann-Whitney test was done to find significant difference across groups I and II for condition III of oral and nasal sentences. The test results indicated that there was no significant deference between groups I and II for condition III of oral [G I – G II ($|z| = 0.56$, $p > 0.05$)] and nasal sentences [G I – G II ($|z| = 1.55$, $p > 0.05$)]. Kruskal Wallis test could not be done because condition III of group III had only one subject data. The data showed that condition III nasalance values of group III was higher for oral sentences compared to condition III scores of other two groups.

4.2.1.4.3 Comparison across conditions

For group I (Palatoplasty), a repeated measure ANOVA was done to determine main effect of conditions on nasalance values of sentences. The results revealed that there was significant main effect for conditions on oral [$F (2, 18) = 4.99$, $P < 0.05$] and nasal [$F (2, 18) = 6.57$, $P < 0.05$] sentences. Post hoc test using Bonferroni correction was done for nasalance values of both oral and nasal sentences. The results revealed that there was significant difference ($p < 0.05$) between condition I (pre surgery) and Condition II (3 months follow ups) for oral sentences. However, no significant difference ($p > 0.05$) was observed across conditions for nasal sentences.



[Group I (GI) - Palatoplasty, Group II (GII) –Pharyngoplasty, Group III (GIII) - Combined Surgery, Condition I (CI) – Pre surgery, Condition II (CII) – 3 months follow up, Condition III (CIII) – 6 months follow up, OS- Oral sentences, NS – Nasal sentences]

Figure 15. Effect of types of surgery on nasalance values of sentences (a- oral and b- nasal) across conditions

The Figure 15 depicts the effects of different types of surgery on nasalance values of oral and nasal sentences. Wilcoxon's signed rank test was done for group II (pharyngoplasty) and group III (combined surgery group) to analyze significant difference between conditions for both sentences (Table 34).

Table 34

Results of Wilcoxon's Signed Rank Test for Sentences across conditions

Conditions		**Types of Surgery**	
		G II	**G III**
		|z|	**|z|**
C I-C II	OS	2.52**	0.73
	NS	2.70**	0.73
C I- C III	OS	1.46	-
	NS	1.82	-
C II- C III	OS	0.36	-
	NS	0.73	-

Note. **P<0.01 * P < 0.05 [Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3months follow up, Condition III (CIII) = 6 months follow up, OS = Oral Sentences, NS = Nasal sentences]

For group II (pharyngoplasty), significant difference was seen for condition I and II. For group III (combined surgery), there was no significant difference between pre and first follow up. Friedman test could not be done to find overall difference because of fewer subjects in condition III for the groups II and III. The data showed that condition III nasalance values for oral sentences were reduced compared to condition I and II.

4.2.1.5 Cineradiographic Evaluation of VPD for Vowels

The cineradiographic evaluation of velopharyngeal closures of all the subjects for vowels (/a/, /i/ and /u/) were rated by three trained speech language pathologist using a rating scale given by Ann Kummer et al. (1995). The speech samples consisted of production of isolated vowels (/a/, /i/ and /u/). The rating scale considered was a four point rating scale (0 = normal and 4= severe). The speech samples obtained were blindfolded across two conditions (pre surgery and 2nd follow up) and presented to the speech language pathologist. Figure 12 shows the flowchart summarizing the analysis carried out for cineradiographic evaluation of velopharyngeal closure for vowels in individuals with VPD.

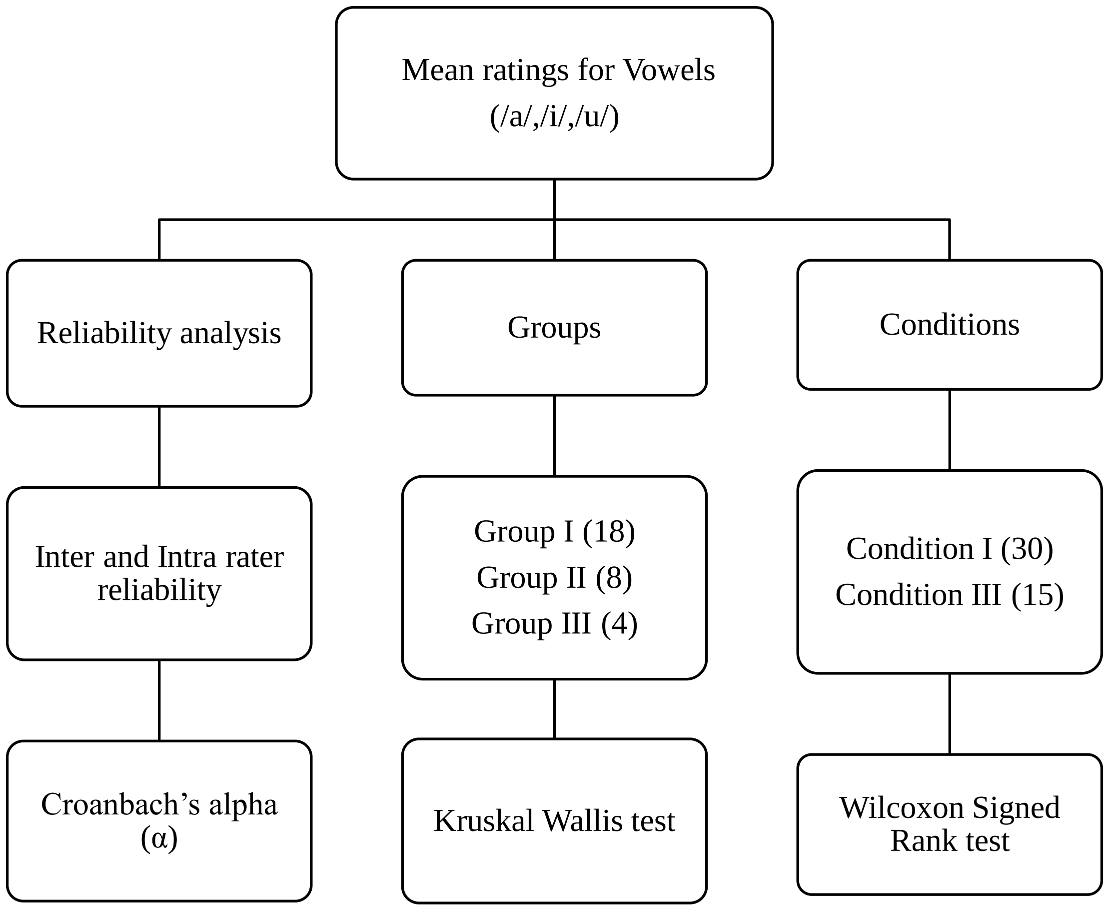


Figure 16. Flow chart for summarizing cineradiographic analysis.

4.2.1.5.1 Reliability for cineradiographic audio-visual recordings of velopharyngeal closure in individuals with VPD across conditions

The inter-rater and intra rater reliability was obtained for ratings done by three trained judges across vowles (/a/, /i/ and /u/). The inter – rater reliability was calculated by obtaining the Cronbach's alpha (α) for vowels across three conditions. The values for all the three conditions ranged from 0.6 to 0.9 which indicated an acceptable to high internal consistency between three judges. The intra rater reliability was obtained by providing 25% of the speech samples to the same judges after one month and cronbach's alpha co-efficient values (α) ranged from 0.74 to 0.90. The cronbach's alpha values for vowels across three conditions are displayed in Table 35.

Table 35

Mean Cronbach's alpha (α) Values for Inter and Intrarater reliability of VPD for Vowels.

Cronbach's alpha (α)	Vowels					
	Interrater Reliability			Intrarater Reliability		
	/a/	/i/	/u/	/a/	/i/	/u/
Condition I	0.80	0.80	0.60	0.82	0.90	0.75
Condition III	0.90	0.88	0.60	0.85	0.85	0.74

High internal consistency was observed among vowels /a/ and /i/ for inter and intrarater reliability. But vowel /u/ had an acceptable internal consistency for ratings between the judges.

4.2.1.5.2 Descriptive statistics for interpretation of cineradiographic audio-visual recordings of velopharyngeal among vowels.

The mean rating scores of velopharyngeal closure for vowels (/a/, /i/ and /u/) across groups and conditions are depicted in Table 36. The greater scores suggest severe VPD and the lesser scores indicate better velopharyngeal closure. In general, the velopharyngeal closure of vowels improved in the condition II (3months follow up) and III (6 months follow up) compared to condition I (pre surgery). The rating scores decreased in follow up conditions for all the vowels indicating improved velopharyngeal closure. The overall mean rating scores were greater for vowel /a/ in the pre-operative conditions followed by vowels /i/ and /u/. In the follow up condition not much variation was seen in the velopharyngeal closure of vowels.

Table 36

Median and IQR for Rating Scores of Velopharyngeal Closure in Vowels

Type of Surgery	Condition I			Condition III			Condition I			Condition III		
	N	***Mdn***	***IQR***	N	***Mdn***	***IQR***	N	***Mdn***	***IQR***	N	***Mdn***	***IQR***
				/a/						**/i/**		
G I	18	3	1	10	2	1	18	2	1.25	10	2	0.25
G II	8	3	1	4	2	1	8	3	1.75	4	2	1
G III	4	2	1	1	2*	0	4	3	1	1	2*	0
Total	30	2	2	15	2	1	30	2	1	15	2	1
				/u/								
G I	18	2	0	10	2	0						
G II	8	2	1	4	2	1						
G III	4	2	1	1	2*	0						
Total	30	2	1	15	2	1						

Note. [Mdn = Median, IQR = Inter Quartile Range, Group I(GI) = Palatoplasty, Group II(GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I(CI) = Pre surgery, Condition II (CII) = 3months follow up, Condition III (CIII) = 6 months follow up, 0 = normal , 1 = mild , 2 = moderate , 3 = severe , 4 = very severe, N = no. of subjects, * = Single subject's data]

4.2.1.5.3 Comparison across groups

Kruskal Wallis test was done to find whether significant difference across groups was noticed on ratings for velopharyngeal closure for vowels in condition I and III. The results indicated that there was no significant difference between groups on condition I and condition III rating of velopharyngeal closure of vowels /a/[C I χ^2 (2) =2.16, p>0.05; C III χ^2 (2) =1.36, p>0.05], /i/ [C I χ^2 (2) =2.69, p>0.05; C III χ^2 (2) =1.63, p>0.05] and /u/ [C I χ^2 (2) =0.87, p>0.05 ; C III χ^2 (2) =2.91, p>0.05] across conditions.

4.2.1.5.4 Comparison across conditions

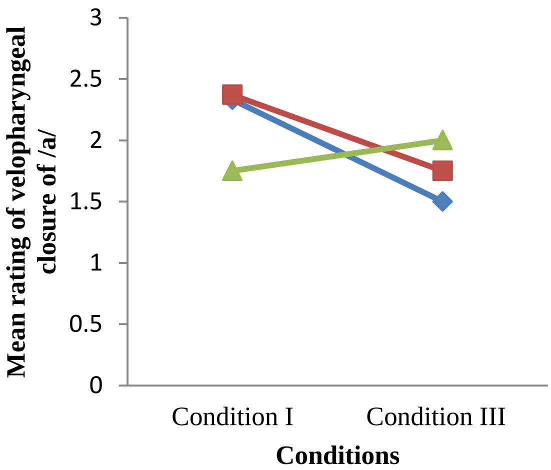
Wilcoxon's signed rank test was done to find any significant difference for ratings of velopharyngeal closure across conditions and groups (Table 37). The results indicated that for group I (palatoplasty), a significant difference between condition I and III values of velopharyngeal closure was seen for isolated vowel /a/ but not for vowel /i/ and /u/. In group II (Pharyngoplasty), the significant difference for vowels was not seen across all the conditions. For group III (combined surgery), Wilcoxon's signed rank test could not be done because there were less than three subjects in that group. Friedman test could not be done to find overall difference because of fewer subjects in condition III for the groups II and III.

Table 37

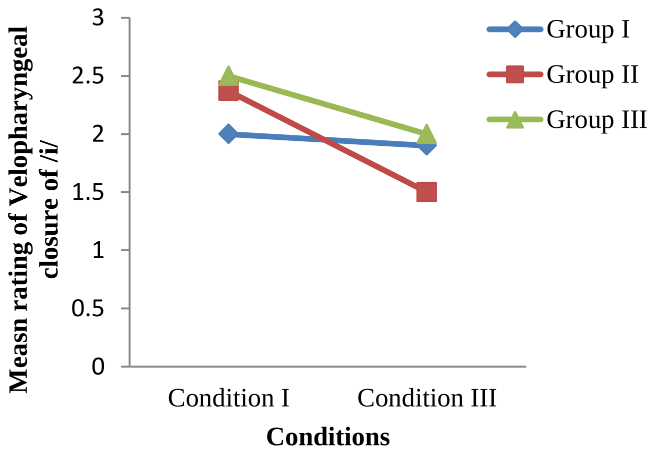
Results of Wilcoxon's Signed Rank Test for Velopharyngeal Closure seen for Vowels

Conditions		**Types of Surgery**		
		G I	**G II**	**G III**
		|z|	**|z|**	**|z|**
C I-C III	/a/	2.69**	1.34	-
	/i/	1.1	1.73	-
	/u/	1	1.41	-

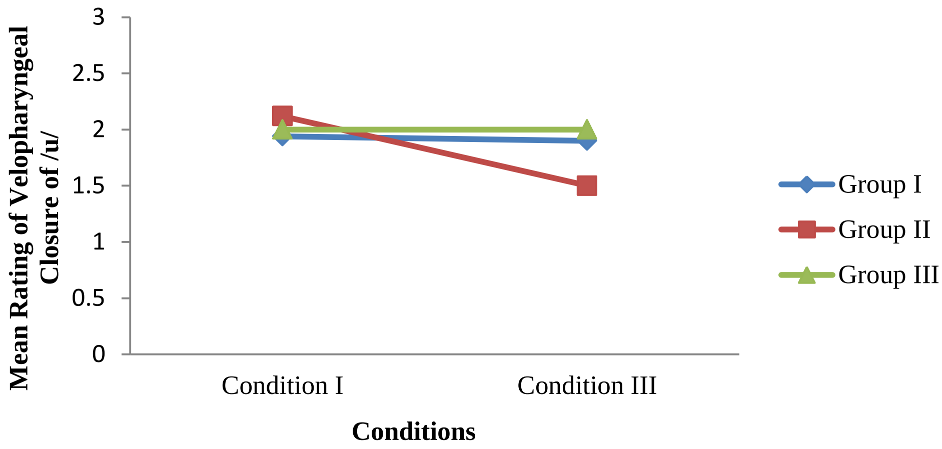
Note. **P<0.01 [Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition III (CIII) = 6 months follow up]



(i)



(ii)



(iii)

[Group I (GI) - Palatoplasty, Group II (GII) –Pharyngoplasty, Group III (GIII) - Combined Surgery, Condition I (CI) – Pre surgery, Condition II (CII) – 3 months follow up, Condition III (CIII) – 6 months follow up]

Figure 17. Effect of types of surgery on velopharyngeal closure of vowels (i- /a/, (ii)- /i/ and (iii)-/u) across conditions.

The figure 17 depicts the median rating values of velopharyngeal closure across conditions for vowels. Among the vowels, vowel /i/ and /u/ had reduced rating scores or improved velopharyngeal closure for pharyngoplasty group in the six months follow up condition.

4.2.2 Perceptual Resonance Characteristics in Individuals with VPD

The perceptual resonance characteristics such as hypernasality, hyponasality, nasal air emission of all the subjects were rated by three trained speech language pathologist using the universal speech outcome rating scale given by Henningsson et al. (2008). The speech samples consisted of three min spontaneous speech on school /leisure activities, standardized oral sentences for hypernasality and nasal air emission. Further standardized nasal sentences were considered for rating hyponasality. The rating scale considered was a four point rating scale (0 =normal and 4= severe). The speech samples obtained were blindfolded across the three conditions (pre surgery, first follow up and 2nd follow up) and presented to the speech language pathologist. The perceptual speech characteristics were subjected to different non-parametric statistical analysis (Figure 18).

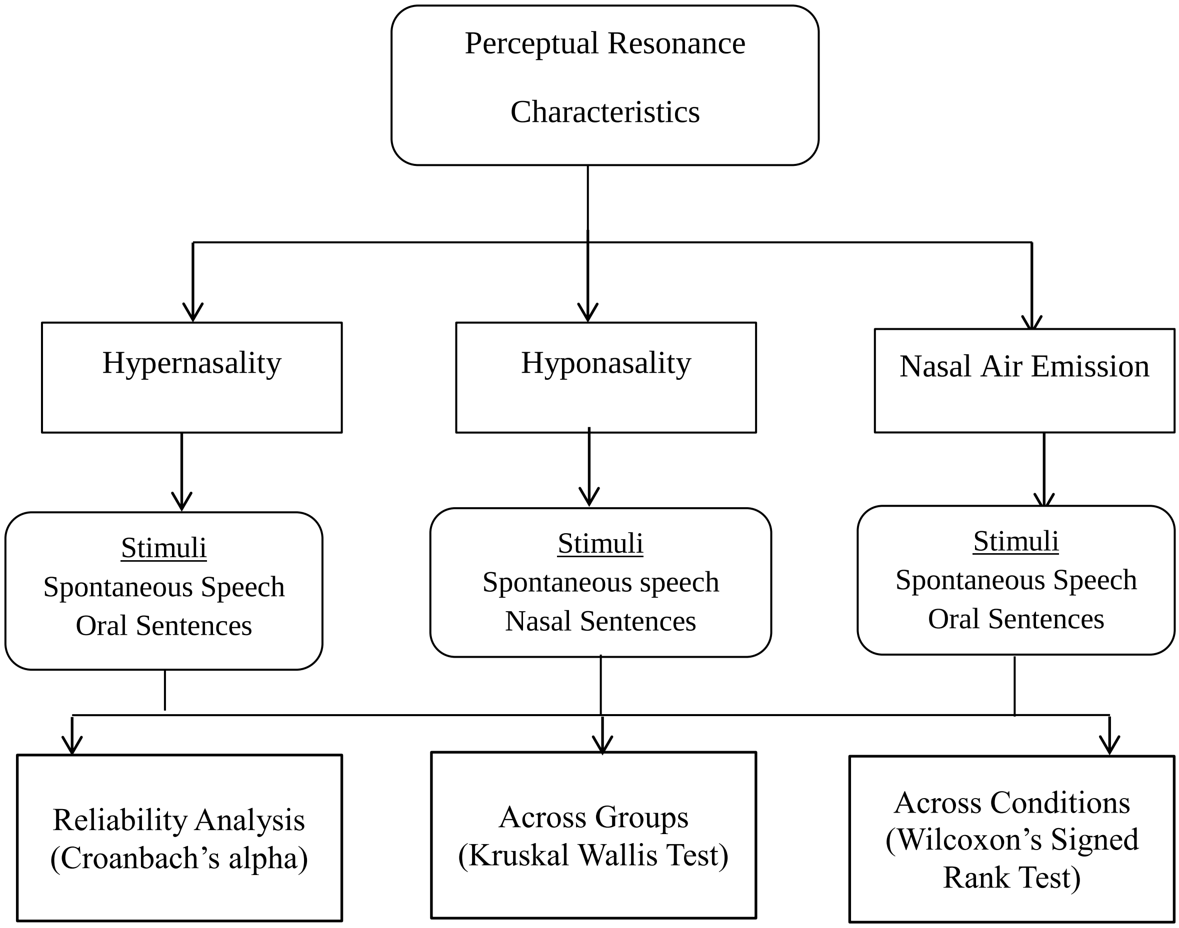


Figure 18. Flow chart for summarizing analysis of perceptual resonance characteristics.

4.2.2.1 Reliability analysis of perceptual speech characteristics

The inter-rater and intra-rater reliability was assessed for ratings obtained by three trained judges for hypernasality, hyponasality and nasal air emission. Mean reliability values were calculated by obtaining the Cronbach's alpha (α) for perceptual speech characteristics of speech samples such as spontaneous speech and oral sentences across three conditions. The inter rater reliability values for all the three conditions were between 0.6 to 0.7 which indicated an acceptable internal consistency between three judges. The intra rater reliability was obtained by providing 25% of the samples to the same judges after one month and cronbach's alpha co-efficient values (α) ranged from 0.74 to 0.89. The cronbach's alpha values for perceptual speech characteristics across three conditions are displayed in Table 38.

Table 38

Mean Inter and Intrarater Reliability of Perceptual Rating done by Judges across Stimuli

Cronbach's alpha (α)	**Interrater Reliability**			**Intrarater Reliability**		
	HN	**HON**	**NAE**	**HN**	**HON**	**NAE**
Spontaneous speech						
Condition I	0.65	0.78	0.77	0.84	0.74	0.83
Condition II	0.67	0.80	0.87	0.82	0.77	0.84
Condition III	0.72	0.77	0.80	0.80	0.78	0.86
Oral sentences						
Condition I	0.63	0.65	0.68	0.85	0.79	0.88
Condition II	0.67	0.68	0.76	0.88	0.83	0.89
Condition III	0.78	0.74	0.61	0.83	0.86	0.85

Note. [HN = Hypernasality, HON = Hyponasality, NAE = Nasal Air Emission]

The high internal consistency was seen between the ratings done by three judges was seen for nasal air emission followed by hypernasality and hyponasality.

4.2.2.2 Hypernasality

The median and inter quartile range for rating scores of hypernasality for spontaneous speech and oral sentences across groups and conditions for individuals with VPD are depicted in Table 39. For spontaneous speech, a slight increase in nasality was observed from condition I to condition III. However, not much difference was observed between condition II and Condition III for oral sentences. The results showed that the overall mean scores for hypernasality increased for spontaneous speech followed by oral sentences across three conditions. The degree of hypernasality reduced from severe in condition I to moderate in condition III.

Table 39

Median and IQR for Rating Scores of Hypernasality across groups

Type of Surgery	***N***	**C I**		***N***	**C II**		**N**	**C III**	
		Mdn	***IQR***		***Mdn***	***IQR***		***Mdn***	***IQR***
				Spontaneous Speech					
G I	18	3	0	18	2	0	10	1	0
G II	8	3	1	8	1	1	4	1	1
G III	4	2	1	4	2	0	1	2*	0.25
Total	30	2	1	30	1	1	15	1	1
				Oral Sentences					
G I	18	3	0.25	18	2	1	10	2	1.25
G II	8	2	1	8	1	0.75	4	1	0
G III	4	2	1	4	2	0	1	2*	0
Total	30	2	1	30	2	1	15	2	2

Note. [Mdn = Median, IQR = Inter Quartile Range, Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up, 0 = normal, 1 = mild, 2 = moderate, 3 = severe, N = no. of subjects, * = Single subject’s data]

4.2.2.2.1 Comparison across groups

Kruskal Wallis test was done to find significant difference across groups on hypernasality for condition I and II. The results showed that there was significant difference between groups on condition I [χ^2 (2) =8.861, $p<0.05$] and condition II hypernasality scores of oral sentences [χ^2 (2) =6.27, $p<0.05$]. Mann-Whitney U test was done for condition I and II hypernasality scores of oral sentences across groups. The results showed significant difference for condition III hypernasality scores between group I and II ($|z|=2.41$, $p<0.05$) and also group II and III ($|z|=2.41$, $p<0.05$). There was no significant difference between group I and II ($|z|=0.34$, $p>0.05$) for condition III scores of hypernasality. Kruskal Wallis test could not be done to compare groups for condition III because of lesser than three subjects in condition III of group III.

4.2.2.2.2 Comparison across conditions

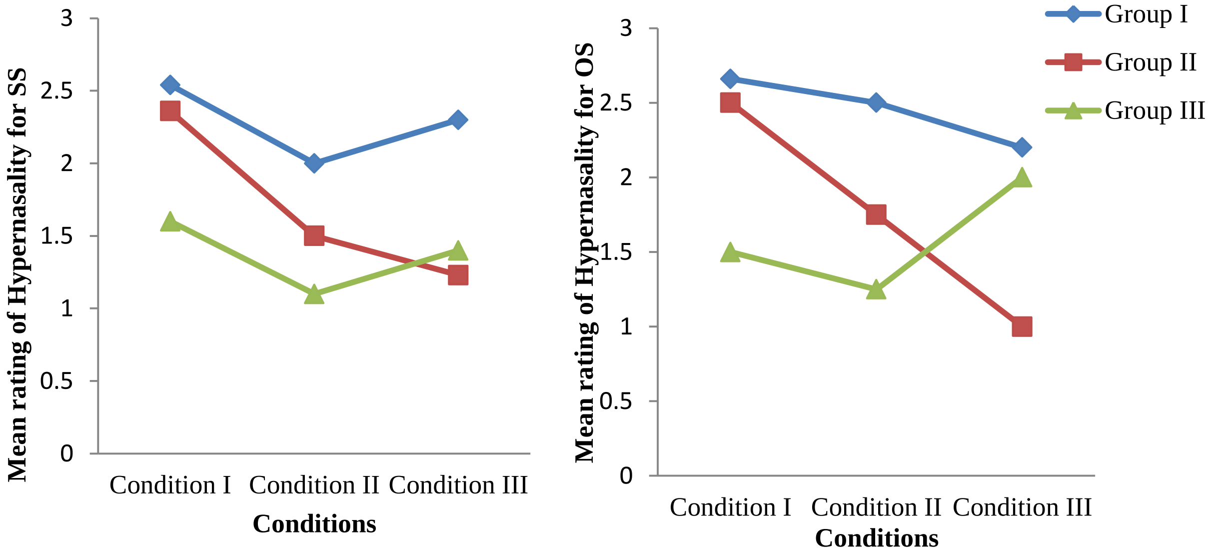
Wilcoxon's signed rank test was done to find significant difference between conditions for hypernasality across groups (Table 40).

Table 40

Results of Wilcoxon's Signed Rank Test for Hypernasality across conditions

Conditions		Types of Surgery		
		G I	G II	G III
		|z|	|z|	|z|
C I-C II	SS	2.81*	2.64*	0.66
	OS	2.91*	2.44**	0.54
C I- C III	SS	2.44*	1.89	-
	OS	2.34*	2.42*	-
C II- CIII	SS	0.31	0.37	-
	OS	0.44	1.00	-

Note. **P<0.01 *P < 0.05 [Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I(CI) = Pre surgery, Condition II (CII) = 3months follow up, Condition III (CIII) = 6 months follow up, SS = Spontaneous Speech, OS = Oral Sentences]



(a) (b)

[Group I (GI) - Palatoplasty, Group II (GII) –Pharyngoplasty, Group III (GIII) - Combined Surgery, Condition I (CI) – Pre surgery, Condition II (CII) – 3months follow up, Condition III (CIII) – 6 months follow up, SS- Spontaneous Speech, OS- Oral Sentences]

Figure 19. Effect of types of surgery on hypernasality (a – spontaneous speech and b- oral sentences) across conditions.

The Figure 19 depicts the effects of different types of surgery on hypernasality rating scores of spontaneous speech and oral sentences. The results showed a significant difference between all the three conditions on hypernasality scores of spontaneous speech and oral sentences for group I (palatoplasty). The significant difference was not seen between condition I and condition III for both the stimuli. There was a significant difference between Condition I and Condition II on hypernasality scores for both the stimuli in group II (pharyngoplasty). Friedman test could not be done to find overall difference because of fewer subjects in condition III for the groups II and III. For group III (combined surgery) significant difference was not observed between conditions for both spontaneous speech and oral sentences. The significant difference was not seen between condition II and III for both the stimuli across groups

4.2.2.3 Hyponasality

The median and inter quartile range for rating scores of hyponasality for spontaneous speech and nasal sentences of the different types of VPD surgery across three conditions for individuals with VPD surgery are depicted in Table 41. The results showed that the overall mean values for hyponasality were found to be near normal across three conditions. The findings indicated that there was no hyponasality present.

Table 41

Median and IQR for Rating Scores of Hyponasality across conditions

Type of Surgery	**N**	**C I**		**N**	**C II**		**N**	**C III**	
		Mdn	***IQR***		***Mdn***	***IQR***		***Mdn***	***IQR***
				Spontaneous Speech					
G I	18	0	0	18	0	0	10	1	0
G II	8	0	1	8	1	0	4	1	1
G III	4	0	1	4	0	0	1	0*	0.25
Total	30	0	1	30	0	1	15	1	1
				Nasal Sentences					
G I	18	0	0.25	18	0	1	10	0	1.25
G II	8	0	1	8	1	0.75	4	1	0
G III	4	0	1	4	0	0	1	0*	0
Total	30	0	1	30	0	1	15	0	2

Note. [Mdn = Median, IQR = Inter Quartile Range, Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3months follow up, Condition III (CIII) = 6 months follow up, 0= normal, 1= mild, 2= moderate, 3 = severe, N = no. of subjects, * = Single subject's data]

4.2.2.3.1 Comparison across groups

Kruskal Wallis test was done to find significant difference across groups on nasalance values of hyponasality for conditions I and III. The results showed that there was no significant difference between the groups on hyponasality scores of oral sentences [C I χ^2 (2) =1.861, p>0.05; C II χ^2 (2) =7.861, p>0.05] and spontaneous speech [C I χ^2 (2) =1.54, p>0.05; C II χ^2 (2) =3.54, p>0.05] across conditions. For condition III, Mann-Whitney test was done to find significant difference across group I and II. The results showed no significant difference across groups for condition III [GI-GII (|z| = 0.57, p>0.05)]. Kruskal Wallis test could not be carried out because the condition III of group III had lesser subjects. The data showed that there was not much difference between the ratings of condition III across groups.

4.2.2.3.2 *Comparison across conditions*

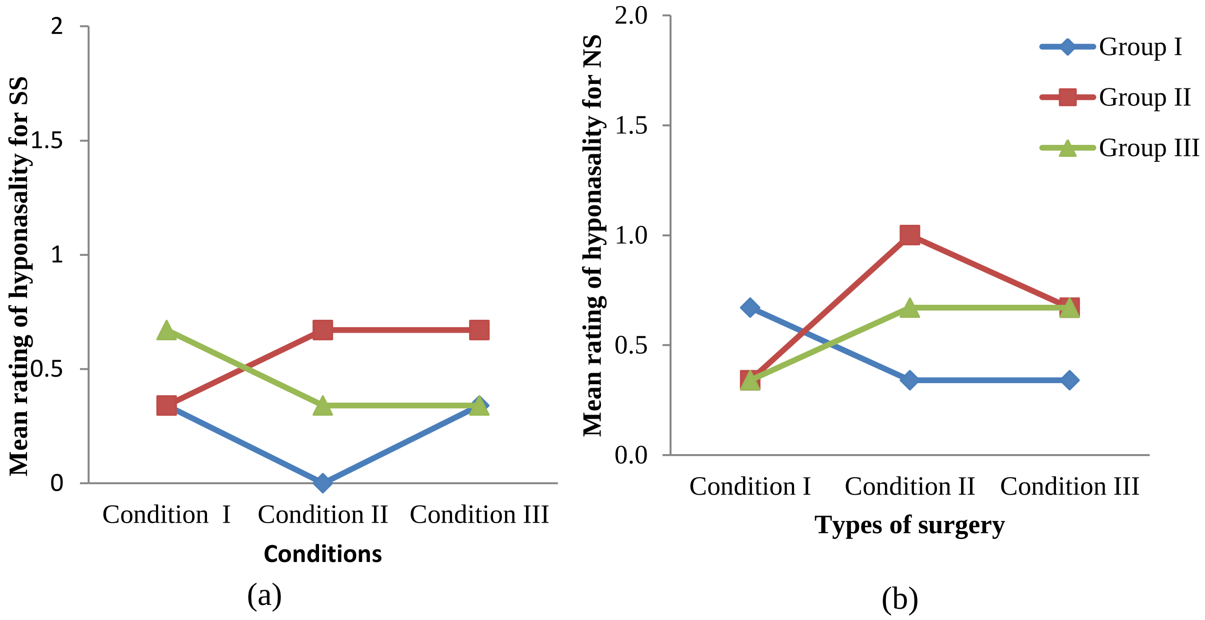
Wilcoxon's signed rank test was done to investigate significant difference between conditions for hyponasality of the groups (Table 42).

Table 42

Results of Wilcoxon's Signed Rank Test for Hyponasality across conditions

Conditions		**Types of Surgery**		
		G I	**G II**	**G III**
		|z|	**|z|**	**|z|**
C I-C II	SS	2.81*	2.64*	0.66
	NS	2.91*	2.44**	0.54
C I- C III	SS	2.44*	1.89	-
	NS	2.34*	2.42*	-
C II- C III	SS	0.31	0.37	-
	NS	0.44	1.00	-

Note. **P<0.01 * P < 0.05 [Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3months follow up, Condition III (CIII) = 6 months follow up, SS = Spontaneous Speech, NS = Nasal Sentences]



[Group I (GI) - Palatoplasty, Group II (GII) –Pharyngoplasty, Group III (GIII) - Combined Surgery, Condition I (CI) – Pre surgery, Condition II (CII) – 3 months follow up, Condition III (CIII) – 6 months follow up, SS- Spontaneous speech, NS- Nasal Sentences]

Figure 20. Types of surgery on hyponasality (a – spontaneous speech and b- nasal sentences) across conditions

Figure 20 indicates the hyponasality ratings for spontaneous speech and nasal sentences. The results showed significant difference between condition I and condition II for group I (palatoplasty) and II (pharyngoplasty) on oral and nasal sentences. And significant difference was noticed between condition I and condition III for both the stimuli for group I (palatoplasty group). In Pharyngoplasty group (group II) the significant difference between condition I and III was noticed for nasal sentences and not for oral sentences. Friedman test could not be done to find overall difference because of fewer subjects in condition III for the groups II and III. The data showed that condition III scores depicts that no hyponasality was seen post operatively.

4.2.2.4 Nasal air emission

The median and inter quartile range for rating scores of nasal air emission across groups and conditions for individuals with VPD surgery are depicted in Table 43. The nasal air emission scores decreased for condition II (3 months follow up) and III (6 months follow up) compared to condition I (pre-surgery). The results showed that the overall median values of nasal air emission were high for spontaneous speech followed by oral sentences across three conditions.

Table 43
Median and IQR for Nasal Air Emission across Groups

Type of Surgery(N)	***N***	**Condition I**		**N**	**Condition II**		**N**	**Condition III**	
		Mdn	***IQR***		***Mdn***	***IQR***		***Mdn***	***IQR***
				Spontaneous Speech					
G I	18	3	0.25	18	2	1	10	2	1.25
G II	8	3	1	8	2	0.75	4	1	0
G III	4	3	1	4	2	0	1	1*	0
Total	30	3	1	30	2	1	15	2	2
				Oral sentences					
G I	18	3	1	18	2	0.25	10	2	1
G II	8	3	1.75	8	2	0.25	4	2	1
G III	4	2	0	4	2	1	1	1*	0
Total	30	2	1	30	1	1	15	1	1

Note. [Mdn = Median, IQR = Inter Quartile Range, Group I (GI) = Palatoplasty, Group II(GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I(CI) = Pre surgery, Condition II (CII) = 3months follow up, Condition III (CIII) = 6 months follow up, 0 = normal, 1= mild, 2 = moderate, 3 = severe, N= no. of subjects, * = Single subject's data]

4.2.2.4.1 Comparison across groups

Kruskal Wallis test was done to find the significant difference across groups on nasalance values of nasal air emission for conditions I and II. The results showed that there was no significant difference across groups for condition I and III nasal air emission scores of oral sentences[C I χ^2 (2) =1.89, p>0.05; C II χ^2 (2) =0.77, p>0.05] and spontaneous speech [C I χ^2 (2) =1.44, p>0.05; C II χ^2 (2) =1.74, p>0.05]. For condition III, Mann-Whitney test was done to find significant difference across group I and II. The results showed no significant difference across groups for condition III of oral sentences [GI-GII (|z| = 0.91, p>0.05)] and spontaneous speech sentences [GI-GII (|z| = 0.86, p>0.05)]. Kruskal Wallis test could not be carried out because the condition III of group III had lesser subjects. The data showed that there was not much difference between the ratings of condition III across groups.

4.2.2.4.2 Comparison across conditions

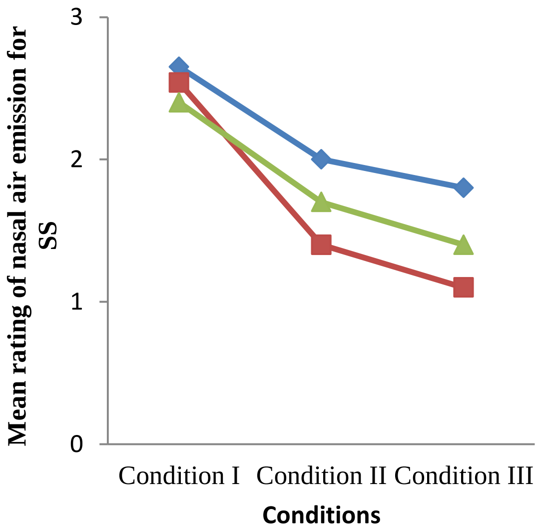
Wilcoxon's signed rank test was done to investigate significant difference between conditions for nasal air emission for the groups. (Table 44).

Table 44

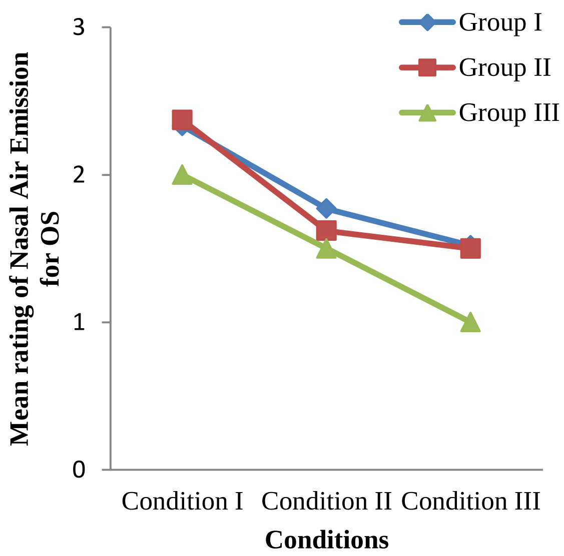
Results of Wilcoxon's Signed Rank Test for Nasal Air Emission across Conditions

Conditions		Types of Surgery		
		GI	GII	GIII
		|z|	|z|	|z|
C I-C II	SS	2.81*	2.64*	0.66
	OS	2.91*	2.44**	0.54
C I- C II	SS	2.44*	1.89	-
	OS	2.34*	2.42*	-
C II- C III	SS	0.31	0.37	-
	OS	0.44	1.00	-

Note * P < 0.05 [Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up, SS = Spontaneous Speech, OS = Oral Sentences]



(a)



(b)

[Group I (GI) - Palatoplasty, Group II (GII) –Pharyngoplasty, Group III (GIII) - Combined Surgery, Condition I (CI) – Pre surgery, Condition II (CII) – 3 months follow up, Condition III (CIII) – 6 months follow up]

Figure 21. Effect of types of surgery on nasal air emission of individuals with VPD across conditions (a- spontaneous Speech, b-oral sentences)

Figure 21 depicts the median ratting scores for nasal air emission for spontaneous speech and oral sentences. Among the types of surgery, group I (palatoplasty) showed a significant difference ($p<0.05$) between conditions on nasal air emission of spontaneous speech and oral sentences. For group II (pharyngoplasty), there was a significant difference ($p<0.05$) noticed between condition I and II for both the stimuli and there was no significant difference seen between condition II and III scores for all the groups. But no significant difference was noticed between condition I and II on nasal air emission for both the stimuli in group III (combined surgery). Friedman test could not be done to find overall difference because of fewer subjects in condition III for the groups II and III. The median rating scores showed that nasal air emission of group III had reduced rating scores to mild degree for both spontaneous speech and oral sentences than condition I and II.

4.2.3 Discussion

The resonance characteristics of individuals with VPD before and after surgical intervention were studied using instrumental and perceptual methods. The instrumental evaluation includes obtaining nasalance values using Nasometer II 6450, across pre and post-operative conditions. First of all the increased nasalance values were observed in the preoperative condition for individuals with VPD. This results is in consonance with the findings in the literature (Bressmann et al., 1998; Sweeney., 2004; Zajac., 2012). The VPD in individuals with RCLP may occur due to scarring of the tissues in the soft palate and failure of the surgical procedure. The increase in the nasalance values is due to the escape of acoustic energy through the nasal cavity during the production of oral consonants. This escape of acoustic energy depends on the size of the velopharyngeal gap. This finding supports the results obtained by the studies in the literature (Dalston et al., 1991; MacKay & Kummer, 1994; Lewis et al., 2000). The other factors contributing to the increase in nasalance values are the presence of articulatory errors and backing errors to post-uvular place which results in inappropriate nasal air emission (Kummer, 2001).

The nasalance values were reduced in both the post-operative conditions (3 and 6 months follow up) compared to preoperative condition. This reduction in the nasalance values may be due to the structural correction of velopharyngeal closure, which resulted in improved oral and nasal coupling during speech production (Zemann, Feichtinger, Santler, & Kärcher, 2006; Yamashita, Carnerio da Sliva, Fukushiro, & Trindade, 2014). The nasometry is often used as an effective method to measure the resonance changes in individuals with VPD following surgical intervention (Whitehill, 2001; Van Lierde et al., 2004). The subjects in the second follow up exhibited lesser nasalance values compared to first follow up and pre-operative condition. This may be because, the subjects considered for the second follow up had attended a minimum of 15 sessions of speech therapy. The major goal considered in speech therapy was to reduce the excess nasality. The nasometry is also used as a tool to measure the speech outcome following various speech therapy techniques (Sweeney et al., 2004). The results of the present study were in consonance with the studies in the literature (Dalston et al., 1991). These results support the need of speech therapy techniques in improving the velopharyngeal closure after surgical intervention in VPD.

The nasalance values were obtained for isolated vowels (/a/, /i/, /u/) in individuals with VPD across conditions. The results showed that among isolated vowels, high vowel /i/ had a greater nasalance values followed by back vowel /u/ and mid vowel /a/. This study supports the findings of the previous studies that tongue height during vowel production significantly influences nasalance, and the results from this study were in agreement with the findings in the literature (Lintz & Sherman, 1961; MacKay & Kummer, 1994; Kuehn & Moon, 1998). During the production of high vowels /i/ and /u/ the tongue tip is placed high in the oral cavity and imposes maximum resistance during the air flow through the oral cavity. But the production of open mid vowel /a/ creates less resistance to the air flow. The results of the present study also support the findings of Moore and Sommers (1973) who reported the greater degree of nasality on high vowels as the high vowels make greater demand upon the valving function i.e higher points of posterior pharyngeal wall/ velar contacts, tighter velopharyngeal seals and greater velar excursion. Back vowels are reported to have lower nasalance values because some of the muscles that pull the body of the tongue back also pull the velum down resulting in tight velopharyngeal closure.

The results also indicated that mean nasalance values were reduced for children compared to adults with VPD. The increase in the nasalance values as age increases may be due to increase in nasal cavity size as the body grows. Although the cranium approaches adult size in early childhood, the facial bones continued to grow into adolescence. The size of the pharynx changes greatly during maturation. It has been shown that with age and height there is a linear increase in the length of pharynx across gender (Rommel et al., 2003). In addition to the increase in the length , there is increase in the 80% of the volume of the nasopharynx from infancy to adulthood (Bergland, 1963) .The developmental changes in speech mechanisms and differences in speech programming are also related to age differences in nasalance scores (Leeper et al., 1992; Becker, 1994). But this difference in the nasalance values across age was not significant in individuals with VPD. It has been proposed that children’s speech is characterized with more reduced nasalance values in connected speech because of anticipatory co-articulation which is a learnt behaviour (Thompson & Hixon, 1979; Flege, 1988). For adults, velopharyngeal port typically begins opening at or near the onset of vowels in the connected speech (Parush & Ostry, 1986).

The nasalance values were also compared across gender. The nasalance values higher for females compared to males but these results were not statistically significant. This higher nasalance values in females may be attributed to anatomical and/or physiological velopharyngeal differences reported across gender (McKerns & Bzoch, 1970; Thompson & Hixon, 1979; Watterson et al., 1994; Zajac & Mayo, 1996; Kuehn & Moon, 1998; Sweeney et al., 2004). Females were reported to have a shorter velum, use less velar elevation, and a greater amount of velar contact against the pharyngeal wall to achieve closure. The angle of contact is acute angle in males and right angle in females (Mc Kerns & Bzoch, 1970). The resonance of voice is influenced by the size, shape and surface of infraglottal and supraglottal resonating structures and cavities. The difference across gender for nasalance values were only 2 scalar points and therefore it was not clinically significant (Trindade, Genero, & Dalton, 1997; Nichols et al., 1999).

Another interesting point noted was that among unvoiced consonants, the palatal /ka/ had lowest nasalance values followed by bilabial /pa/ and velar /ta/. In voiced consonants, the velar /ga/ had higher nasalance values followed by palatal /da/ and bilabial /ba/ in the context of vowel /a/. The voiced pressure consonants (/b/, /d/, /g/) showed greater nasalance values compared to unvoiced consonants (/p/, /t/, /k/) across different vowel context. These results were similar to the findings reported in the literature (Lintz & Sherman, 1961; MacKay & Kummer, 1994; Kuehn & Moon, 1998; Gopisankar, & Pushpavathi, 2008). The authors investigated the influence of phonetic elements in relation to the perception of nasality. According to the authors, individual consonant environments (i.e., voicing, manner, and place) exerted different influences. Voicing produced the greatest effects on nasal perception. Vowels in voiced environments and fricative environments were found to be longer in duration, lower in fundamental frequency, and greater in intensity than vowels in unvoiced or plosive environments. The perception of nasality increased when these acoustic correlates accompanied the phonetic context. The unvoiced consonant production had greater velar height compared to voiced consonants. The same factor that increases the height of velar contact during speech also increases the firmness of closure. The perceived nasality of pressure consonants in descending order were voiceless plosive, voiceless fricative, voiced plosive, and voiced fricative (i.e., /k, t, s, f,g, d, v, z/). The authors concluded that the tongue height and voicing were found to have the most significant influence on the perception of nasality.

Among the standardized sentences, nasal sentences had higher nasalance values followed by oral sentences. Similar results were seen for speech samples consists of CV syllables in the context of vowels (/a/, /i/ and /u/). The observed variation in nasalance across oral and nasal stimuli sentences could be attributed to velopharyngeal closure and also the influence of phonetic nasal content of individual stimuli on the nasalance values (Fletcher, Adams & Mc Cutcheon, 1989). This is consistent with the findings of nasalance values being vowel dependent when using short stimuli (Fletcher et al., 1989; Lewis et al., 2000; Mac-Kay & Kummer, 1994; Lewis, Watterson & Quint, 2000). In individuals with VPD during the production of oral sentences, the velum is held low which results in emission of air through nasal cavity which further increases the nasalance values. The results were in consonance with the study done by Lewis et al. (2000).

In the present study, nasometric results revealed that the difference between the pre- and post-operative mean nasalance values of oral and nasal sentences were statistically highly significant after surgery in Furlow group, while less significant in pharyngoplasty and combined surgery group. The theoretical advantages of furlows double opposing z plasty technique (FDOZ) include soft palatal lengthening through the use of opposing Z-plasties of the oral and nasal mucosa and concomitant reconstruction of the levator sling. In addition to providing increased velar length, the Z-plasty prevents longitudinal scar contracture and subsequent velar shortening (Gunther, Wisser, Cohen, & Brown, 1998; Guneren, & Uysal, 2004). These results were in consonance with previous studies (Armour et al., 2005; Abyholm et al., 2005; Dailey, Karnell, Karnell & Candy, 2006; Wojcicki & Wojcjcka, 2010).

The other instrumental evaluation of resonance was carried out to evaluate the velopharyngeal closure by obtaining cineradiographic videos of individuals with VPD across vowels (/a/, /i/, and /u/). The results indicated that degree of velopharyngeal closure was severe in the pre -operative condition. The degree of VPD varied among individuals with repaired cleft lip and palate. The speech characteristics depend on the degree of VPD. In the present study the speech was characterized by the hypernasality, misarticulation, nasal air emission and unintelligible speech. This may be due to the severe VPD which was observed in pre-operative condition. The severe VPD is reported by Sommerald et al. (2004) as severe deficit in the degree of velopharyngeal closure may occur due to the poor muscle orientation in VPD which hampers the velar elevation during velopharyngeal closure.

The degree of velopharyngeal closure improved from severe to moderate from pre to post operative condition. This may be because of the secondary surgical intervention which majorly alters the muscle orientation of the soft palate which further improves the velopharyngeal closure. The moderate velopharyngeal closure can be caused due to various factors such as age of surgery, the type of surgery used, severity of the VPD, the width of the soft palate modified and post-operative speech therapy (Kummer, 2001).

Among vowels, the results showed that pre-operative rating scores were higher for vowel /a/ followed by /u/ and /i/. Post-operative ratings were high for vowel /i/ followed by vowel /u/ and /a/. This indicates that the velopharyngeal closure for isolated vowels was moderate in pre-operative condition which improved after surgery. These results may be due to the velopharyngeal physiological changes that happen when the tongue tip is placed high in the oral cavity and imposes maximum resistance during the air flow through the oral cavity. But during the production of open mid vowel /a/ less resistance is created to the air flow (Moll, 1962; Bell-Berti et al., 1979). There was no consistent difference between the tense/lax or front /back features of vowel sounds (Seaver & Kuehn, 1980). Kuehn (1982) suggested that the target velar position during velopharyngeal closure does not depend on the activity of individual muscle (i.e levator veli palatine) and it is the combined activity of more than one velar muscle (i.e levator, palatoglossus, palatopharyngeus, superior constrictor). This suggests that the velopharyngeal closure pattern is heterogeneous and it varied across vowels.

Among the types of surgery, palatoplasty indicated a significant difference between pre and post-operative ratings of velopharyngeal opening of isolated vowel /a/ but not for vowel /i/ and /u/. The palatoplasty results in the anatomic changes that are necessary for speech and velopharyngeal function. The significant increase in the velar length and velar thickness was observed after Fulow’s double opposing Z plasty through radiographic and aerodynamic measurements which is an important factor considered for post–operative improvement in the velopharyngeal closure (D’Antanio, 2000). The velar height achievement might have been inadequate for the palatoplasty and pharyngoplasty surgeries which resulted in not much change in the vowel /i/. These results are in consonance with findings in the literature (Kasten, Buchman, Stevenson, & Berger, 1997; Loksen, et. al, 2003; Amour, Fischbach, Klaiman, & Fisher, 2005). In the present study, minimal gap in velopharyngeal closure was observed among vowels. The complete velopharyngeal closure was not achieved in all the isolated vowels in the six months follow up study. This suggests the need for speech therapy in these individuals with VPD.

The perceptual assessment of nasality showed that hypernasality and nasal air emission had significantly reduced median values in their post-operative conditions compared to pre-operative condition. For hyponasality, there was not much change between the mean perceptual rating of pre and two post-operative conditions because of the presence of hypernasality in all the subjects across conditions. The hypernasality and nasal air emission may be attributed to the presence of VPD in the pre-operative condition. Similar results were observed by various researchers in their previous studies (Karling, Henningsson, Larson & Isberg, 1999; Tonz, Schmid, Graf, Heeb, Weissen & Kaiser , 2002 ; Dailey, Karnell, Karnell & Candy, 2006 ; Elbarbary & Ghandour , 2008 ; Van Lierde , Bonte , Baudonck , Cauwenberge & De Leenheer, 2008; Wojcicki & Wojcjcka , 2010). Among the types of surgery, palatoplasty and pharyngoplasty had significantly improved nasality values in the post-operative condition.

The mean perceptual rating for hypernasality was found to be higher for spontaneous speech compared to oral sentences. The reason for the increased hypernasality in individuals with VPD is that velopharyngeal port is open during the production of oral sounds and the sound resonates in both the oral and nasal cavities. This increased hypernasality for spontaneous speech may be due to the larger gap or the timing delay in the opening or closing of the velopharyngeal port (Dotevall, Lohmander-Agerskov, Ejnell, & Bake, 2002). The nasal air emission always accompanies the hypernasality because both occur during the open velopharyngeal valve. They were usually present during the production of the pressure consonants and the compensatory articulatory productions like pharyngeal fricatives or stops (Kummer, 2001; Johns, Rohrich, & Awada, 2003). Apart from this, the velar height varies with the rate of syllables production in stimuli composed of vowels oral and nasal consonants. The extent of velar displacement decreases with increase in the rate of speech. Also the contact of velum to the posterior pharyngeal wall varies depending on the consonants and vowels. Hence there is variability in the nasalance values.

The palatoplasty (Furlows double opposing z plasty) and pharyngoplasty procedures were effective in significantly reducing the hypernasality and nasal air emission when the selection of the procedure was based on the pre-operative perceptual ratings and velopharyngeal physiology. In the present study, both the types of surgery did not create any airway obstruction because there was not much change in the hyponasality rating scores of both post-operative conditions when compared to pre–operative. The poorer outcomes in the second post-operative condition of pharyngoplasty are more likely because the subjects considered for the pharyngoplasty group had moderate to severe VPD. So these subjects would have slightly increased hypernasality in the long term follow up because of reduction in the scars that are present after the surgery.

In the present study good inter-rater reliability (α= 0.6-0.7) was observed on perceptual speech characteristics. Among the characteristics, reliability was lowest for hypernasality, implying that it was the most difficult variable to assess. Other studies have reported higher reliability figures for perceptual assessment of hypernasality by expert listeners. Lewis et al. (2003) reported weighted kappa values between 0.71 and 0.73 for three expert judges. Pulkkinen, Haapanen, Laitinen, Paaso and Ranta (2001) reported 91-94% exact agreement on various variables. The factors that contribute to the inter-rater reliability depends on the factors such as length of the stimuli , quality of speech recording , experience of the judges, description of the scalar points, the number of variables that are simultaneously assessed for the speech samples presented (Watterson, Lewis, Allord, Sulprizio, & O'Neill, 2007). But in the present study moderate or good inter-rater reliability was obtained and this eliminates the possibility of involvement or contribution of above factors.

4.3 Effect of Surgery on Speech Intelligibility of Individuals with VPD

The speech intelligibility was assessed based on three minute spontaneous speech samples and standardized sentences both quantitatively and qualitatively (Figure 22) . The subjects consisted of thirty individuals with VPD and the above mentioned speech samples were collected across three conditions (pre-operative, first follow up and 2^{nd} follow up). Further to find the effect of type of surgery on speech intelligibility, the subjects were grouped based on types of surgery such as palatoplasty (18), pharyngoplasty (8) and combined surgery (4). The obtained speech samples were blinded across conditions rated using a four point rating scale (0-3) by Henningsson et al. (2008) [0- normal, 1-mild, 2- moderate and 3-severe] by trained judges for perceptual analysis. The percentage of speech intelligibility was calculated for spontaneous speech samples across conditions as quantitative measure.

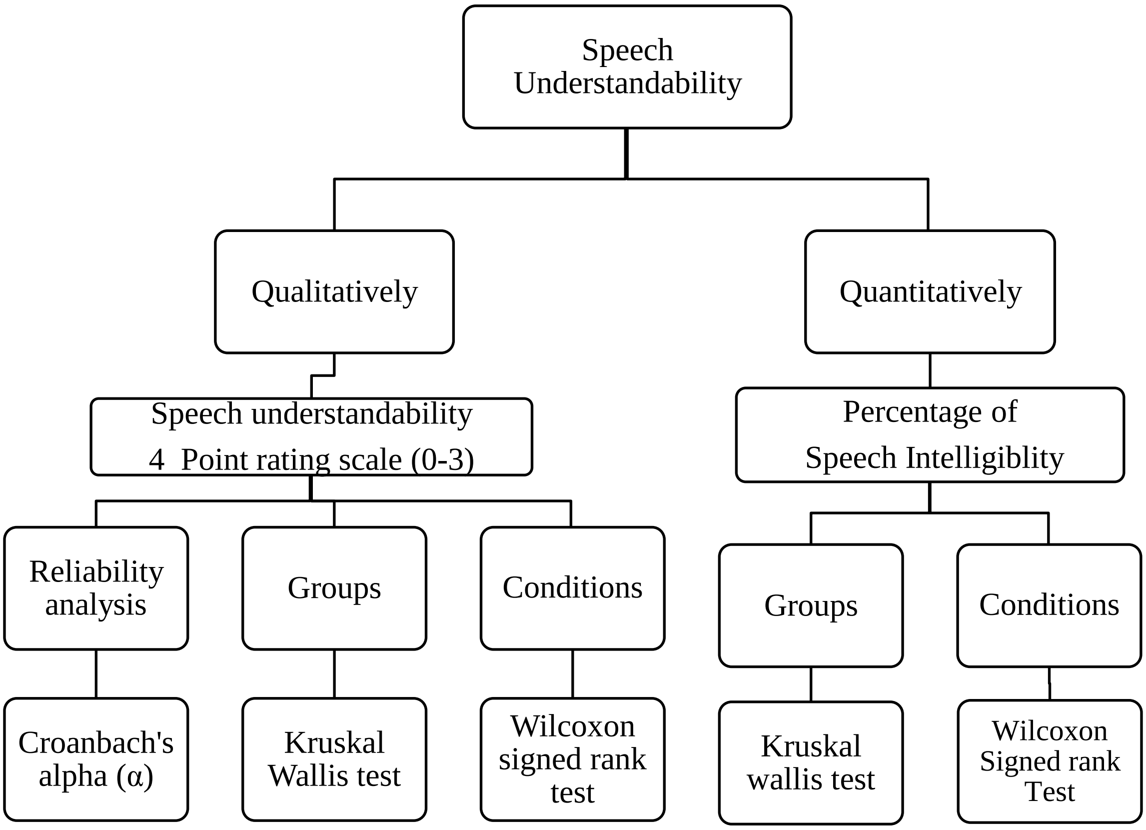


Figure 22. Flow chart for summarizing analysis of speech understandability

4.3.1 Reliability of Perceptual Ratings of Speech Understandability across Conditions.

The inter and intra rater reliability were assessed based on ratings done by three trained judges for the speech samples. The inter-rater reliability was calculated by obtaining the Cronbach's alpha (α) for both spontaneous speech and sentences across three conditions. The inter rater reliability values for all the three conditions were in the range of 0.6 to 0.7. This depicts an acceptable internal consistency between three judges. The intra rater reliability was obtained by providing 25% of the samples to the same judges after one month and cronbach's alpha co-efficient values (α) ranged from 0.74 to 0.85. The cronbach's alpha values for spontaneous speech and sentences across three are depicted in table 45.

Table 45

Mean Cronbach's Alpha (α) Value for Inter-rater and Intra rater reliability of Speech Understandability

Cronbach's alpha (α)	**Speech Understandability**			
	Interrater Reliability		**Intrarater Reliability**	
	SS	**OS**	**SS**	**OS**
Condition I	0.66	0.78	0.78	0.80
Condition II	0.61	0.71	0.82	0.74
Condition III	0.77	0.76	0.80	0.85

Note. [Condition I (CI) = Pre surgery, Condition II (CII) = 3months follow up, Condition III (CIII) = 6 months follow up, SS = Spontaneous Speech, OS = Oral Sentences]

4.3.2 Perceptual Evaluation of Speech Understandability

The median and IQR for perceptual ratings of speech understandability for spontaneous speech and sentences of individuals with VPD across conditions and types of surgery are depicted in Table 46. The results showed a gradual improvement in the overall mean rating scores of speech understandability from condition I (pre surgery) to condition III (6 months follow up). The degree of speech understandability was severe in the condition I and it was rated to milder degree in the condition III. On comparison between the types of speech samples there was not much difference seen in the overall ratings of speech understandability.

Table 46

Median and IQR for Ratings of Speech Understandability across Groups

Type of Surgery	N	C I *Mdn*	C I *IQR*	N	C II *Mdn*	C II *IQR*	N	C III *Mdn*	C III *QR*
				Spontaneous Speech					
G I	18	2	0.25	18	2	1	10	2	1
G II	8	3	1	8	2	0.75	4	2	1
G III	4	3	1	4	2	0	1	1*	0
Total	30	3	1	30	2	1	15	2	2
				Oral Sentences					
G I	18	2	0.50	18	1	1	10	1	1
G II	8	3	0.75	8	2	1	4	1	0.75
G III	4	3	0	4	2	1	1	1*	0
Total	30	2	1	30	1	1	15	1	1

Note. [Mdn = Median, IQR = Inter Quartile Range, Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up, 0 = normal, 1- mild, 2 = moderate, 3 = severe, * = Single subject's data, N= no. of subjects]

4.3.2.1 Comparison across groups

Kruskal Wallis test was done to investigate whether significant difference was observed across groups on mean perceptual rating of speech understandability across spontaneous speech and sentences for conditions I and II. The results showed that there was no significant difference between groups on mean ratings for speech understandability of spontaneous speech [C I χ^2 (2) =8.23, p>0.05; C II χ^2 (2) =4.89, p>0.05] and oral sentences [C Iχ^2 (2) =5.06, p>0.05; C II χ^2 (2) =2.41, p>0.05]. For condition III, Mann-Whitney test was done to find significant difference across group I and II. The results showed no significant difference across groups for condition III of oral sentences [GI-GII (|z| = 0.18, p>0.05)] and spontaneous speech sentences [GI-GII (|z| = 1.18, p>0.05)]. Kruskal Wallis test could not be carried out because the condition III of group III had lesser subjects. The data showed that there was not much difference between the ratings of condition III across groups.

4.3.2.2 Comparison across conditions

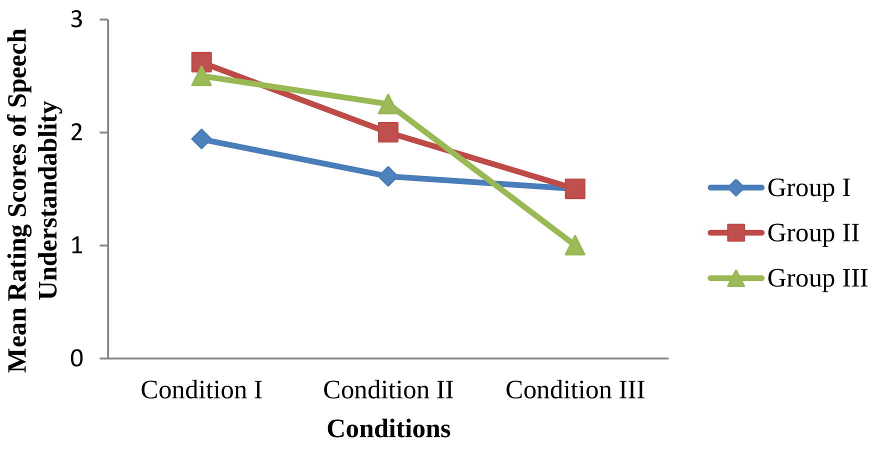
Wilcoxon's signed rank test was done to find any significant difference between conditions for mean rating scores of speech understandability across groups (Table 47).

Table 47

Results of Wilcoxon's Signed Rank Test for Speech Understandability

Conditions		**Types of Surgery**		
		G I	**G II**	**G III**
		|z|	|z|	|z|
C I-C II	SS	1.73	2.23*	0.57
	OS	2.88**	2.30*	2.00*
C I – C III	SS	1.73	2.00*	-
	OS	2.03**	1.63	-
C II – C III	SS	1.13	0.57	-
	OS	1.00	1.00	-

Note. **P<0.01 * P < 0.05 [Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I(CI) = Pre surgery, Condition II (CII) = 3months follow up, Condition III (CIII) = 6 months follow up, SS = Spontaneous speech, OS = Oral sentences]



[Group I (GI) - Palatoplasty, Group II (GII) –Pharyngoplasty, Group III (GIII) - Combined Surgery, Condition I (CI) – Pre surgery, Condition II (CII) – 3months follow up, Condition III (CIII) – 6 months follow up]

Figure 23. Types of surgery on perceptual ratings of speech understandability of spontaneous speech across conditions

The Figure 23 depicts the effects of different types of surgery on mean perceptual rating scores of speech intelligiblity for spontaneous speech across three conditions. The results showed significant difference between conditions on mean percentage scores for oral sentences in group I (palatoplasty) but not for spontaneous speech. For group II (pharyngoplasty), there was a significant difference between condition I and II on mean percentage scores of spontaneous speech and oral sentences. Friedman test could not be done to find overall difference because of fewer subjects in condition III for the groups II and III. The data showed no difference seen for condition I and III scores of group II (pharyngoplasty) and group III (combined surgery).

4.3.3 Percentage of Speech Intelligiblity (SI %)

The mean, standard deviation and median of speech intelligibility (SI %) for spontaneous speech samples across groups and conditions are depicted in Table 48. The results showed a gradual increase in the mean percentage of speech intelligibility from condition I (pre surgery) to condition III (6 months follow up. Among the different types of velopharyngeal surgery the group II (pharyngoplasty) had a greater condition III rating scores followed by group III (combined surgery) and group I (palatoplasty).

Table 48

Mean, Standard Deviation and Median of Speech Intelligibility (%) for Spontaneous Speech across groups

Type of Surgery	**Speech Intelligiblity (%)**											
		Condition I				**Condition II**				**Condition III**		
	N	**M**	**SD**	**Mdn**	**N**	**M**	**SD**	**Mdn**	**N**	**M**	**SD**	**Mdn**
G I	18	52.72	6.85	52.50	18	58.16	6.51	57.00	10	76.09	8.04	75.00
G II	8	53.37	3.74	54.00	8	61.50	7.92	58.00	4	82.00	6.08	85.00
G III	4	46.25	3.30	46.50	4	64.00	3.74	64.50	1	77.00*	-	77.00
Total	30	52.03	6.86	50.00	30	59.83	6.80	58.00	15	77.33	7.57	77.00

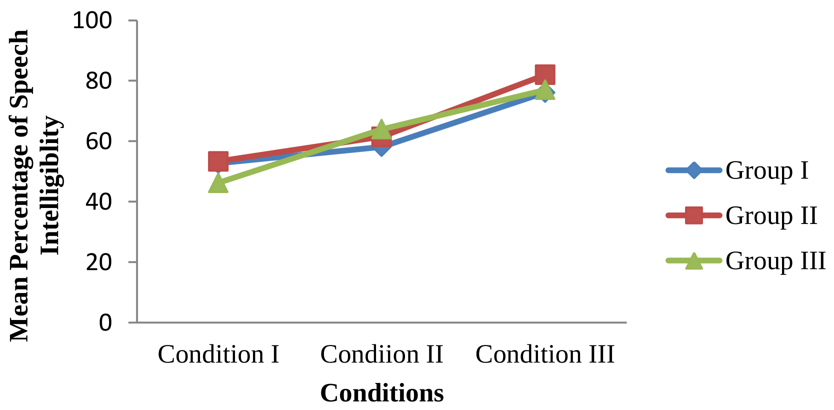
Note [M = Mean, SD = Standard Deviation, Mdn = Median, Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up, * = Single subject's data, N= no. of subjects, - = No standard deviation]

4.3.3.1 Comparison across groups

Kruskal Wallis test was done to find significant difference across groups on mean percentage scores for speech intelligiblity of spontaneous speech for condition I and II. The results showed that there was no significant difference between groups on mean percentage scores for speech intelligiblity of spontaneous speech [C I χ^2 (2) =3.19, p>0.05; C II χ^2 (2) =4.11, p>0.05]. For Condition III, Mann-Whitney test was done to find significant difference across group I and II. The results showed no significant difference across groups for condition III spontaneous [GI-GII (|z| = 1.18, p>0.05)]. Kruskal Wallis test could not be carried out because the condition III of group III had lesser subjects. The data showed that there was not much difference between the ratings of condition III across groups.

4.3.3.2 Comparison across conditions

Among the types of surgery, palatoplasty group followed a normal distribution so a repeated measure ANOVA was done to find main effect of conditions on percentage of speech intelligiblity. The results revealed that there was significant main effect of conditions on percentage of speech intelligiblity [F (2, 20) = 50.47, P < 0.01; Effect size (η_p^2) =0.93].



[Group I (GI) - Palatoplasty, Group II (GII) –Pharyngoplasty, Group III (GIII) - Combined Surgery, Condition I (CI) – Pre surgery, Condition II (CII) – 3 months follow up, Condition III (CIII) – 6 months follow up]

Figure 24. Percentage of speech Intelligiblity (%) of spontaneous speech across conditions

Post hoc tests using Bonferroni correction was done for percentage of speech intelligiblity. The results revealed that there was significant difference ($p < 0.05$) between all the three conditions on percentage of speech intelligiblity. The Figure 24 depicts the effect of different types of surgery on mean percentage of speech intelligiblity across three conditions.

Wilcoxon's signed rank test was done for group II (pharyngoplasty) and group III (combined surgery group) to find the significant difference across conditions for mean percentage of speech intelligiblity for spontaneous speech across groups (Table 49).

Table 49
Results of Wilcoxon's Signed Rank Test for Percentage of Speech Intelligiblity

Conditions		**Types of Surgery**	
		G II	**G III**
		|z|	**|z|**
C I-C II	SS	2.52**	1.84
C I- C III	SS	1.84	-
C II- C III	SS	1.84	-

Note **P<0.01 *P <0.05 [Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3months follow up, Condition III (CIII) = 6 months follow up, SS = Spontaneous speech]

The results indicated that for group II (pharyngoplasty), significant difference was observed only between condition I and II mean percentage scores. There was no significant difference seen for condition III scores of pharyngoplasty with condition I and II. Friedman test could not be done to find overall difference because of fewer subjects in condition III for the groups II and III. For group III (combined surgery), significant difference was not observed between condition I and II. The condition III scores showed improvement in the speech intelligiblity scores compared to condition I and II.

4.3.4 Discussion

The principal goal of any intervention methods by the craniofacial team in individuals with cleft lip and palate is to ensure that their speech is understandable to the listeners (Gunther, Wisser, Cohen, & Brown, 1998; Khosla, Marby, & Castiglione, 2008). Hence speech intelligiblity /understandability is an outcome measure to evaluate the success of team in implementing their intervention goals. The speech understandability was defined as the 'degree to which the speaker's message can be understandable to the listener' (Henningsson et al., 2008). The rating scales are the most commonly used methods for assessment of speech understandability in individuals with cleft lip and palate (Kuehn & Moller, 2000; Peterson –Falzone, Hardin – Jones & Karnell, 2001; Whitehill, Lee, & Chun, 2002)

In the present study the perceptual rating of speech understandability was carried out by three experienced SLP's for spontaneous speech and oral sentences. The results showed that speech understandability was rated low for both spontaneous speech and sentences in individuals with VPD in pre-operative condition. In the post-operative conditions, there was significant improvement in speech understandability for oral sentences. For spontaneous speech samples, reduced rating scores for speech understandability was noticed for second follow up condition and it was not statistically significant. These results suggest that connected speech is more complex and it is best representative of individuals every day speech (Howard & Lohmander, 2011).

In general, percentage of speech intelligiblity was found to be low in pre-operative condition of individuals with VPD. This result was consistent finding seen in children with cleft lip and palate when compared to non-cleft group (Van Lierde et al., 2002; Van Lierde et al., 2004; Hodge & Goztke, 2007). This reduction in the speech intelligiblity scores in the pre-operative condition was due to the presence of misarticulation and resonance problems such as nasal air emission, hypernasality in individuals with VPD. The percentage of speech intelligiblity scores improved from 52% to 77% in the second post-operative follow up conditions. This result supports the findings of speech outcome studies on speech intelligiblity in the literature (Kuehn & Moller, 2000; Konst et al., 2000).

The second post-operative recordings were carried out in 15 participants after a period of 6 months following surgical management. Only 50% of the total subjects could be followed up for the second post-operative recordings and they underwent a minimum of 15 sessions of speech therapy before recording the speech samples. The speech therapy goals were focused to improve oral breath stream, teaching place of articulation, improving speech intelligiblity. Among the types of surgery, pharyngoplasty had greater impact on speech intelligiblity scores followed by combined surgery and palatoplasty. The same trend was observed for articulatory errors across types of surgery. These results may be due to the persistent articulatory errors which might have developed as a habituated pattern in individuals who underwent palatoplasty. This further led to reduction in the speech intelligiblity scores. This suggests the strong negative relationship between speech intelligiblity scores and articulation errors.

Persson, Lohmander, and Elander (2006) reported that children undergoing early repair of the palate exhibited significantly better speech outcomes compared to individuals with late repair. In the present study the individuals with repaired cleft palate underwent velopharyngeal surgery at a mean age range of 12.4 years which was considered late when compared to regular mean age of 4 years (ACPA, 2007). The inter rater reliability of individuals with VPD for speech understandability was evaluated using Croanbach’s alpha (α) coefficient. The results showed good inter – rater reliability obtained between the judges for speech intelligiblity.

4.4 Effect of Surgery on Dsyphonia Severity Index in Individuals with VPD

Dysphonia severity index (DSI), a multidimensional parameter for measuring the quality of voice was extracted using Lingwaves voice clinic pro software. The parameters included in the calculation of DSI are maximum phonation time (MPT), highest fundamental frequency (H Fo), lowest intensity (I- low) and jitter (%). These parameters were obtained during the phonation of vowel /a/ in children (n=22) and adults (n=8) across gender and surgery. The results of the voice characteristics in individuals with VPD were grouped into two categories based on age, children (22) and adults (8). Due to the reduced sample size, non-parametric analysis was carried out for both the groups (Figure 25) and the results were described in the following sections.

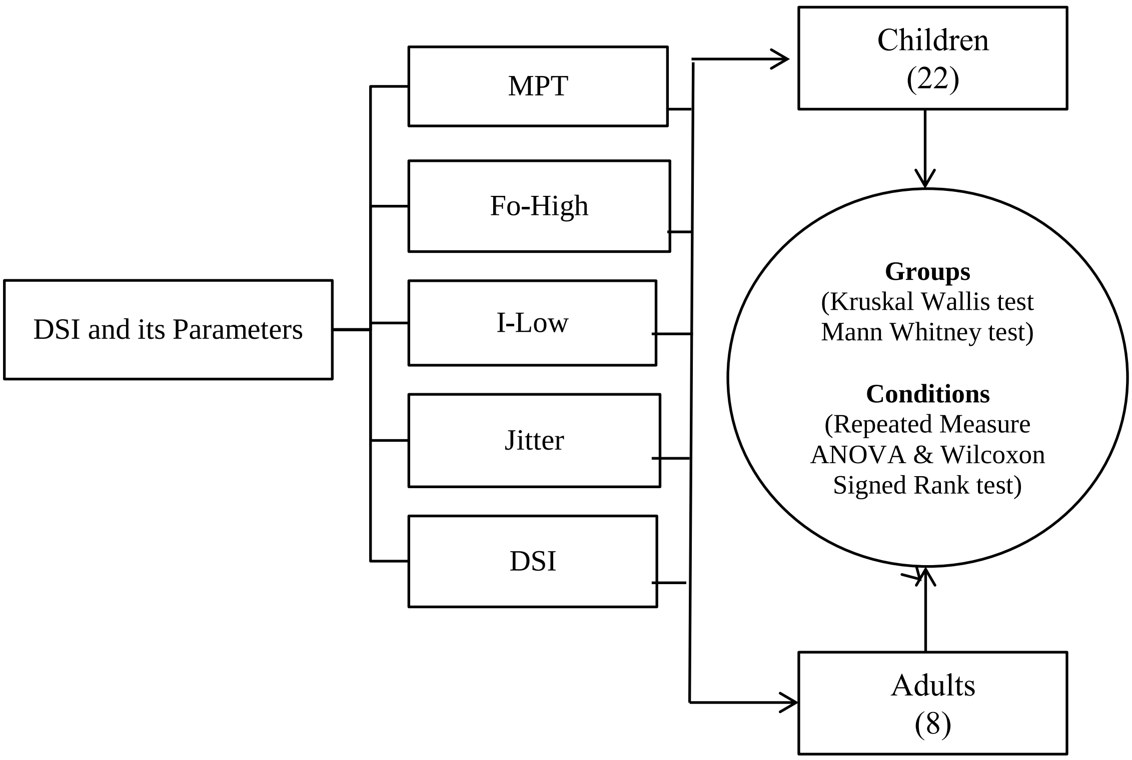


Figure 25. Flow chart for summarizing analysis of DSI and its parameters.

4.4.1 Dysphonia Severity Index (DSI) in children

The mean, standard deviation and median of DSI values obtained on phonation of vowel /a/ across gender, conditions and types of surgery are depicted for children (Table 50). In general, the mean DSI values increased in the condition II (3 months follow up) and III (6 months follow up) compared to condition I (presurgery). The mean DSI values for male children ranged from 1.15 to 1.78 preoperatively and 3.02 to 3.89 postoperatively. As there were no male children in the group III (combined surgery), mean DSI values could not be calculated. The mean DSI values ranged from 2.33 to 2.51 preoperatively and 2.78 to 3.90 post operatively in the female population. Compared to male subjects, females had greater DSI values across conditions.

Table 50

Mean, Standard Deviation and Median for DSI of Children

Age	Type of Surgery	DSI											
		Condition I				Condition II				Condition III			
		N	*M*	*SD*	*Mdn*	N	*M*	*SD*	*Mdn*	N	*M*	*SD*	*Mdn*
Males (n=12)	G I	11	1.78	1.26	2.1	11	3.02	0.78	3.30	7	3.26	0.58	3.40
	G II	1	1.15*	-	1.15	1	3.89*	-	3.89	-	-	-	-
	G III	-	-	-	-	-	-	-	-	-	-	-	-
	Total	12	1.73	1.21	2.09	12	3.09	0.79	3.35	7	3.26	0.58	3.40
Females (n =10)	G I	6	2.51	0.61	2.70	6	3.11	0.84	3.05	2	2.78	1.29	2.78
	G II	2	2.40	0.70	2.40	2	2.78	0.26	2.78	2	2.95	0.07	2.95
	G III	2	2.33	1.97	2.33	2	3.81	0.30	3.81	1	3.90*	-	3.90
	Total	10	2.45	0.52	2.53	10	3.19	0.73	3.08	5	3.07	0.79	3.00

Note. [M = Mean, Mdn = Median, SD = Standard deviation, Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up, , * = Single subject's data , N= no. of subjects, - = No data / No Standard deviation]

4.4.1.1 Comparison across groups

Kruskal Wallis test was done to find the significant difference across types of surgery on DSI values for condition I and II in children. The results showed no significant difference across types of surgery on DSI values of conditions I and II [C I χ^2 (2) =0.56, p>0.05; C II χ^2 (2) =2.76, p>0.05]. For Condition III, Mann-Whitney test was done to find significant difference across group I and II. The results showed no significant difference across groups for condition III of DSI [GI-GII (|z| = 1.18, p>0.05)]. Kruskal Wallis test could not be carried out because the condition III of group III had lesser subjects. The data showed that there was not much difference between the ratings of condition III across groups.

4.4.1.2 Comparison across conditions

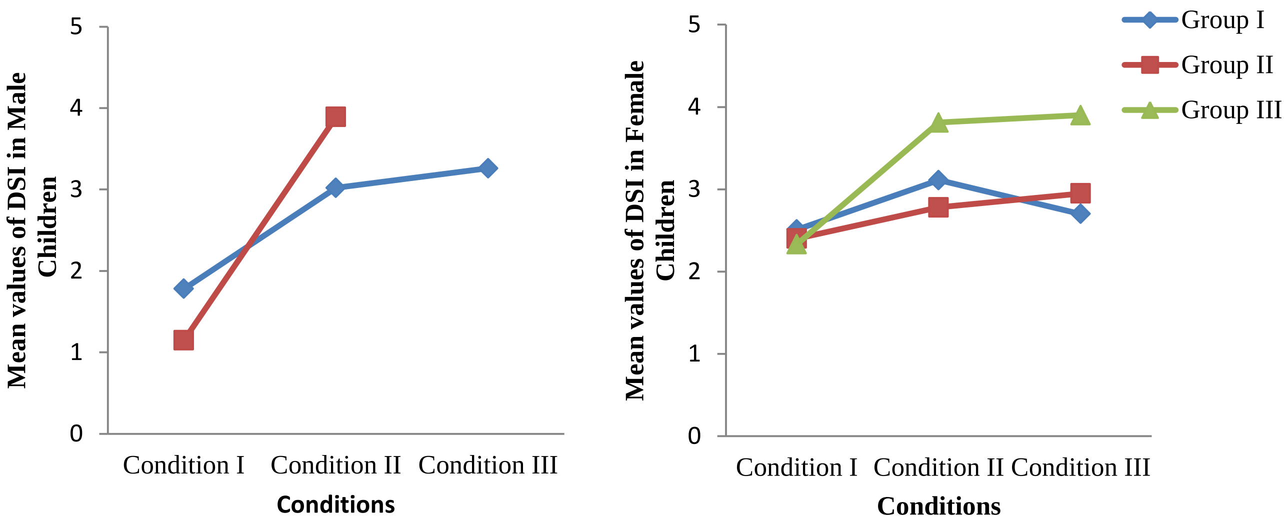
In children, for group I (palatoplasty), a repeated measure ANOVA was done to determine any statistically significant difference for DSI values across conditions. The results revealed significant main effect between conditions and mean DSI values [F (2, 16) = 5.49, P < 0.01; Effect size (η_p^2) =0.94]. Post hoc test using Bonferroni correction was done for DSI values for children. The results revealed no significant difference (p < 0.05) between the conditions for DSI values. For group II (pharyngoplasty) and group III (combined surgery), Wilcoxon's signed rank test was done to compare the DSI values across conditions and gender in children (Table 51).

Table 51

Results of Wilcoxon's Signed Rank Test for DSI in Children across conditions

Conditions		**Types of Surgery**	
		G II	**G III**
		|z|	**|z|**
C I-C II	M	-	-
	F	1.34	1.34
C I- C III	M	-	-
	F	1.34	-
C II- C III	M	-	-
	F	0.44	-

Note. p > 0.05 . [Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up]



(a) (b)

Figure 26. Effect of type of surgery on DSI values of children (a- males and b- females) across condition.

The results depicted that for female subjects, there was no significant difference for DSI values across conditions for both types of surgery. For male children, statistical values could not be calculated for group II and III because of lack of subjects. Frideman test could not be done to find the overall significance because of lesser subjects in condition III. For females, improved DSI values were seen I condition III compared to other conditions.

4.4.2 Dysphonia Severity Index (DSI) in adults

The mean, standard deviation and median of DSI values obtained on phonation of vowel /a/ across gender, conditions and types of surgery are depicted for adults (Table 52). In general, the mean DSI values increased in the condition II and III compared to condition I. The mean DSI values for adult males ranged from 1.04 to 3.3 preoperatively and 3.00 to 4.00 post-operatively. The mean DSI values ranged from 2.85 to 3.40 preoperatively and 3.50 to 4.80 post operatively for female population. As there were no female subjects in the palatoplasty group, mean DSI values could not be calculated. Compared to males, females had a greater DSI values across conditions. Adult participants had greater DSI values compared to children across conditions.

Table 52

Mean, Standard deviation and Median for DSI in Adults

Age	Type of Surgery	DSI											
		Condition I				Condition II				Condition III			
		N	***M***	***SD***	***Mdn***	N	***M***	***SD***	***Mdn***	N	***M***	***SD***	***Mdn***
Males (n= 5)	G I	1	1.04*	-	1.04	1	3.07	-	3.07	1	3.70*	-	3.70
	G II	3	2.75	1.12	2.98	3	3.00	1.13	3.48	1	4.00*	-	4.00
	G III	1	3.30*	-	3.30	1	4.70*	-	4.70	-	-	-	-
	Total	4	2.54	1.77	2.95	4	3.35	1.09	3.48	2	3.85	0.21	3.85
Females (n=3)	G I	-	-	-	-	-	-	-	-	-	-	-	-
	G II	2	2.85	0.91	2.85	2	3.70	0.00	3.70	1	3.50*	-	3.50
	G III	1	3.40*	-	3.40	1	4.80*	-	4.80	-	-	-	-
	Total	3	3.03	0.72	3.40	3	4.06	0.63	3.70	1	3.50	-	3.50

Note. [M = Mean, Mdn = Median, SD = Standard deviation, Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up, * = Single subject's data , N= no. of subjects, - = No data / No Standard deviation]

4.4.2.1 Comparison across groups

Kruskal Wallis test was done to find the significant difference across groups on DSI values for conditions I and II in adults. The results depicted no significant difference between groups on DSI values of all the three conditions I and II [C I χ^2 (2) =2.45, p>0.05; C II χ^2 (2) =4.5, p>0.05]. For condition III, statistical analysis could not be carried out because of lesser or one subject in each group. The data for condition III did not vary across groups.

4.4.2.2 Comparison across conditions

Wilcoxon's signed rank test was done to compare the DSI values across conditions and gender in adults. The results showed that significant difference was not observed between condition I and II for both the gender [Males (|z|=1.75, p>0.05); Females (|z|=1.00, p>0.05)] in the group II (pharyngoplasty). The statistical values could not be calculated for group I (palatoplasty) and group III (combined surgery) in adult subjects because of non-availability of subjects in that surgery groups. Friedman test could not be done to find overall difference because of fewer subjects in condition III for the groups II and III.

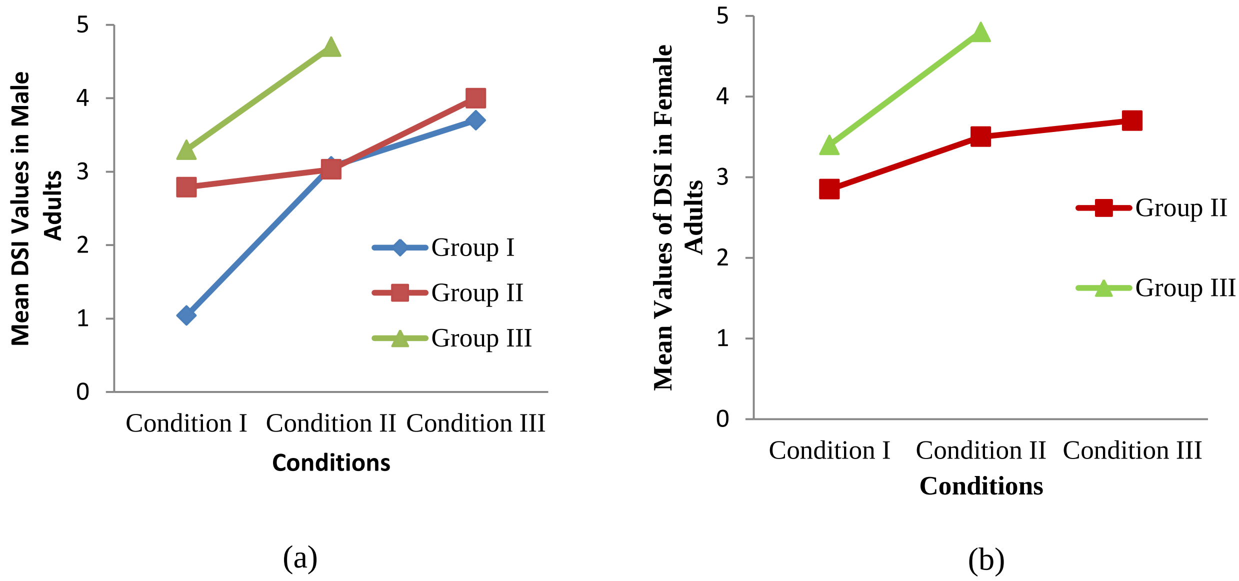


*Figure 27.*Types of surgery on DSI values of adults (a- males and b- females) across conditions

Figure 27 depicts the effect of types of surgery on DSI values of male and female adults across three conditions. The pre-operative DSI values were represented by dotted blue lines for both the gender. The graph showed that pre-operative DSI values were low for males compared females. As post-operative scores improved significantly in male adults compared to female adults.

4.5.6 Discussion

The voice problems in individuals with VPD have been previously reported in the literature (Mc Williams et al., 1969; D'Antanio et al., 1988; Zajac & Linville, 1989; Lewis et al., 1993; Van Lierde et al., 2003). The voice problems observed in individuals with VPD were hoarseness with or without vocal pathology, breathiness, reduced loudness, restricted pitch range, and tense strained voice quality. One of the aims of the present study was to compare the voice characteristics in individuals with VPD before and after surgery.

The present study investigated voice characteristics in 30 individuals with VPD (22 children and 8 adults) before and after surgery. The voice characteristics in individuals with VPD were further grouped according to age and gender because of the anatomical or structural variations of the larynx. The DSI, an objective voice quality measure was carried out in all the subjects preoperatively, three and six months post-operatively. DSI values were obtained from a weighted combination of four parameters such as maximum phonation time (MPT), highest fundamental frequency (Fo High), lowest Intensity (Ilow dB) and jitter (%).

The individuals with VPD showed reduced maximum phonation time, lesser maximum pitch, low intensity and increased jitter in the pre-operative condition and these measures improved after surgical intervention. This result supports the findings of previous studies (Lewis, Andreassen, Leeper, Macrae, & Thomas, 1993; Van Lierde, De Bodt, Baetens, Schrauwen, Van Cauwenberge, 2003; Zajac, & Linville, 1989) where the individuals with cleft palate had demonstrated increased frequency perturbations. The disordered laryngeal system leads to alterations in the aerodynamic or neuromuscular event due to the imbalance in the oral and nasal coupling in the presence of VPD (Zajac & Linville, 1989). During speech production, the function of velopharyngeal port is to alter the air flow rate and transglottal pressures but in individuals with VPD, they try to compensate for these changes by increasing the glottal resistance. These efforts to regulate aerodynamic and neuromuscular process in the presence of oral nasal imbalance leads to increase in jitter values.

The reduced maximum pitch (Fo high) was noticed in individuals with VPD when compared with normative data in the literature (Baken & Orlikoff, 2000; Jayakumar & Savithri, 2012). The reduction in the high Fo values were seen across gender (Rampp, & Counihan, 1970; Flint, 1964). These individuals use a reduced Fo as a strategy to minimize the hypernasality. The present study supports the previous study by Boone and McFarlane (1971) who suggested that a reduction in Fo can decrease the perception of hypernasality. But it is not clear how well these reduced Fo will have an influence on the hypernasality because an increase in frequency coincides with increase in intensity and respiratory effort. But in individuals with VPD this increase in respiratory effort is lost through the open velopharyngeal port. There was little known about the relationship between frequency and hypernasality (Peterson –Falzone, 2001).

The statistical analysis revealed that post-operative DSI scores were better than pre-operative condition across gender in both adults and children. The vocal qualities of females were found to be better than males across conditions in both children and adults. Fletcher (1947) reported the opening phase of the vocal cord to be different during the presence of hypernasality and he also reported that the pattern of movement was asymmetrical. The results of the present study are similar to the findings of the earlier literature reporting an increase in the incidence of hoarseness in individuals with VPD compared to normal individuals. The degree of dysphonia in individuals with VPD is reported to be 12 to 43% higher than normal (Grunwell, Brondsted, Henningsson et al., 2000; Timmons, Wyatt & Murphy, 2001; Hocevar-Boltezar, Jarc, & Kozelj, 2006). The increase in hoarseness in individuals with VPD may be due to laryngeal system trying to compensate for abnormal velopharyngeal valving (Lewis, Andreassen, Leeper, Macrae, & Thomas, 1993; Van Lierde, Claeys, De Bodt, & Van Cauwenberge, 2004).

Individuals with VPD are also associated with poor articulation and increased incidence of hypernasality. The poor articulation is often compensated by the use of pharyngeal and glottal sounds. The glottal stops in particular have been indicated in literature to cause hoarseness (D'Antonio, Muntz, Province, & Marsh, 1988; Van Lierdde et al., 2004). In the present study among the articulation errors pharyngeal fricatives (10.71%) and glottal stops (11.25%) were found to be more among the substitution errors. This compensatory articulatory behavior of substituting posterior sounds for anterior sounds was due to VPD. This further result in strained or hoarse voice. After the second follow up recordings that is after 15 sessions of speech therapy these articulation errors such as glottal stops (5.50%) and pharyngeal fricatives (6.66%) reduced significantly compared to pre surgery and first follow up. This reduction in the articulation errors had significant positive relationship with the hoarseness which relates to the improvement in the DSI values of individuals with VPD.

Hamming, Finkelstein and Sidman (2009) explained the cause for voice problem in individuals with VPD as using greater adductory force on the laryngeal structures in order to reduce nasality and reach a certain vocal intensity. This gives the impression that there is no single definite cause for hoarseness in individuals with VPD, suggesting that it is mostly multifactorial in nature. The individuals considered for the present study had moderate dysphonia (1.4 to 2.2) preoperatively and these values reduced significantly during the second post-operative condition to slight dysphonia (3.3 to 4.3).

According to Peterson –Falzone (2007) the increased respiratory effort which makes the vocal fold to hyper adduct does not change the intraoral breath in pressure in individuals with VPD and it lost through inefficient velopharyngeal mechanism. The decreased voice quality (DSI values) in male participants compared to female subjects in this present study supports the findings of Van Lierde et al. (2003). These findings enlighten the need for specific voice therapy goals in male participants with VPD. The mean dysphonia severity index for pre-operative condition was found to be 1.75, a moderate dysphonia and six months postoperatively it was 3.50, a slight dysphonia. This was in concordance with the study by Van Lierde et al (2008) he reported an increase in DSI scores postoperatively after VPD surgery. The author reported that the overall voice quality of individuals with VPD after long time follow up was 1.7 (range of 0-4.8).The study suggests that careful differential diagnosis is essential in the management of these laryngeal problems which are perhaps the result of laryngeal modification compensatory to poor velopharyngeal valving mechanisms. Hence a detailed evaluation of voice characteristics is essential before and after surgical intervention of individuals with VPD.

4.5 Relationship between instrumental and perceptual evaluation of Individuals with VPD

The association between instrumental and perceptual evaluation of resonance characteristics of individuals with VPD were studied using spearman's correlation co-efficient (rho). The association was further divided on two categories that is the association between nasalance values and perceptual speech characteristics of resonance. And the other one is relationship between nasalance values and perceptual ratings of velopharyngeal closure. The stimulus considered for the association between nasalance and perceptual speech characteristics of resonance was standardized oral sentences .And isolated vowels (/a/, /i/ and /u/) were considered for investigating the relationship between nasalance values an perceptual velopharyngeal closure.

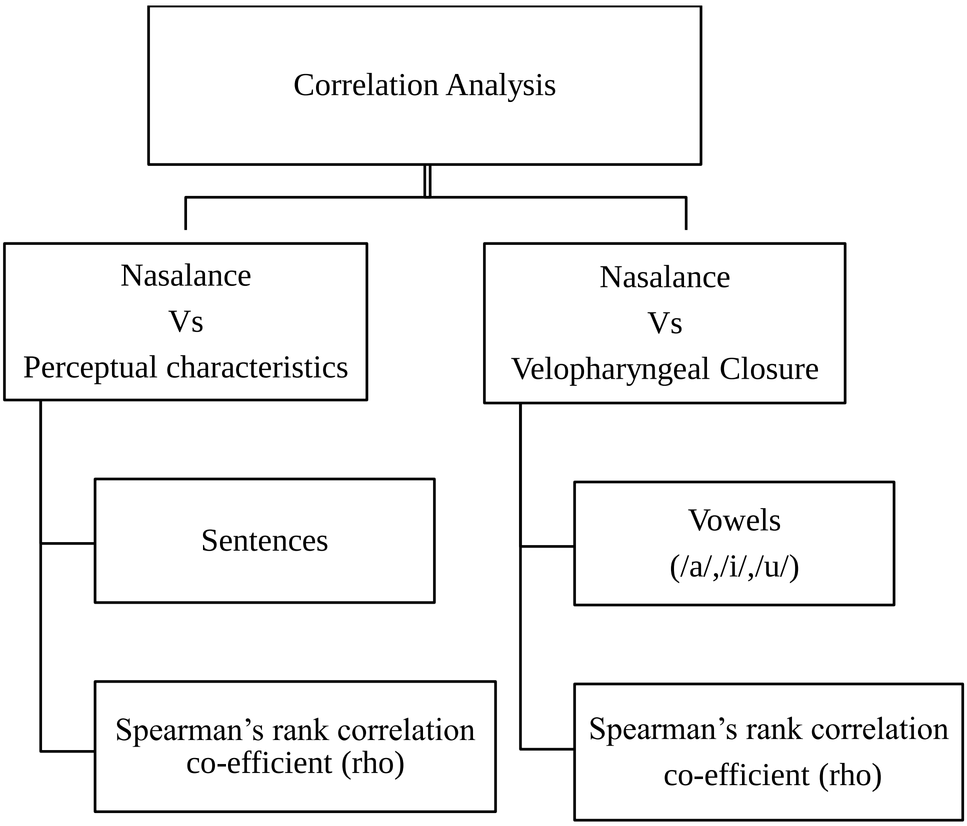


Figure 28. Flow chart summarizing the correlation analysis

4.5.1 The Relationship between Nasalance Values and Perceptual Resonance Characteristics

The association between instrumental and perceptual methods of assessement were evaluated using spearman's rank correlation co-efficient (rho). The correlation co-efficient values were obtained by comparing mean nasalance values and perceptual resonance characteristics of oral sentences. These correlation co-efficient's are tabulated below (Table 53).

Table 53

Correlation between Nasalance Values and Perceptual Rating of Resonance

Parameters	C I HNOS	C II HNOS	C III HNOS	C I NEOS	C II NEOS	C III NEOS
C I NOS	0.424*	0.518**	0.201	0.517	0.225**	0.310
C II NOS	0.377*	0.350	0.187	0.353	0.437*	0.124
C III NOS	0.220	0.254	0.456	0.127	0.239	0.155

Note. *p value <0.05 levels **p value <0.01 levels [PreNOS = presurgery nasalance values for oral sentences, FPostNOS = First follow up nasalance values for oral sentences, SPostNOS = Second follow up nasalance values for oral sentences, PreHNOS = Presurgery hypernasality for oral sentences, FPostHNOS = First follow up hypernasality for oral sentences, SPostHNOS = Second follow up hypernasality for oral sentences , PreNEOS = Presurgery nasal air emission for oral sentences, FPostNEOS = First follow up nasal air emission for oral sentences, SPostNEOS = Second follow up nasal air emission for oral sentences]

The results showed that correlation between nasalance values and perceptual rating of resonance parameters for oral sentences was found to vary from weak to moderate positive relationship. The presurgery nasalance values for oral sentences had moderate relationship with presurgery rating of hypernasality and nasal air emission. For first follow up conditions, nasalance values of oral sentences showed weak positive relationship with hypernasality and nasal air emission. And for second follow up of nasalance values of oral sentences, moderate relationship was observed for hypernasality and no relationship was seen for nasal air emission. Overall the Spearmann's correlation co-efficient (rho) values ranged from 0.35 to 0.52 for the relationship between nasalance values and perceptual rating of resonance for oral sentences.

4.5.2 The Relationship between Nasalance Values and Velopharyngeal Dysfunction

The relationship between nasalance values and perceptual ratings of velopharyngeal dysfunction for isolated vowels (/a/, /i/ and /u/) was also studied using spearman's rank correlation co-efficient (rho). The results are depicted in the Table 54. Overall, moderate to very strong positive relationship was observed between nasalance values and inadequate velopharyngeal closure for isolated vowels across conditions.

Table 54

Correlation between Nasalance Values and Velopharyngeal closure

Parameters	PreVCa	PostVCa	PreVCi	PostVCi	PreVCu	PostVCu
PreNa	0.80**	0.11	0.364*	0.276	0.142	0.523**
SPostNa	0.156	0.589*	0.023	0.411	0.156	0.312
PreNi	0.242	0.063	0.847**	0.597*	0.423	0.058
SpostNi	0.171	0.111	0.027	0.470	0.138	0.194
PreNu	0.477**	0.016	0.455**	0.424	0.690*	0.329
SPostNu	0.219	0.732**	0.016	0.001	0.362	0.701**

Note. *p value <0.05 levels **p value <0.01 levels [PreNa = presurgery nasalance values for vowel /a/, SPostNa = Second follow up nasalance values for vowel /a/ , PreNi = presurgery nasalance values for vowel /i/, SPostNi = Second follow up nasalance values for vowel /i/, PreNu = presurgery nasalance values for vowel /u/, SPostNu = Second follow up nasalance values for vowel /u/, PreVCa = Presurgery velopharyngeal closure for vowel /a/ , PostVCa = Follow up velopharyngeal closure for vowel /a/, PreVCi = Presurgery velopharyngeal closure for vowel /i/ , PostVCi = Follow up velopharyngeal closure for vowel /i/, PreVCu = Presurgery velopharyngeal closure for vowel /u/ , PostVCu = Follow up velopharyngeal closure for vowel /u/]

In the present study, the rating scale was used to rate the velopharyngeal closure. The higher the rating scores, poorer the velopharyngeal closure. In presurgery condition, for all the three vowels (/a/, /i/ and /u/) a strong relationship was observed between nasalance values and ratings of velopharyngeal closure. For post-operative conditions, moderate relationship was found between the above mention variables.

4.6.3 Discussion

One of the objectives of the present study was to investigate the relationship between perceptual and instrumental evaluation of resonance in individuals with VPD. Although literature supports perceptual evaluation by the speech-language pathologist as the “gold standard” for evaluating nasal resonance (Sweeney & Sell, 2008), a latest survey of cleft palate/craniofacial professionals showed that there appears to be no standard protocol for perceptual assessments. Additionally, perceptual rating scales are intrinsically inconsistent due to factors such as differences in listener bias and experience (Kummer et al., 2012). But, American Cleft Palate - Craniofacial Association (ACPA) recommend the importance of including both perceptual and instrumental measures when performing preoperative and postoperative speech assessments (ACPA, 2000).

In the present study the perceptual evaluation of nasality was studied using a four point universal rating scale proposed by Henningsson et al. (2008) and the instrumental evaluation of nasality was assessed using Nasometer. The results revealed weak to moderate relationship between perceptual rating of nasality and nasalance values for oral sentences. The earlier studies report moderate correlations between expert judge’s perceptual ratings of nasality and nasalance values (e.g. Dalston, 1991, Sweeney & Sell, 2008). But the present study does not support other studies which had reported higher correlation value of r = 0.74 (Paynter et al. 1991, Watterson, Lewis, & Deutsch, 1998). Overall, the research provides evocative evidence of considerable positive relationship between nasalance and nasality in individuals with VPD when tested with non-nasal sentences.

In the perspective of these studies, it is evident that the choice of stimuli is one of the factors that can extensively influence nasalance and nasality measures, as well as the outcomes of correlational measures. Nasalance values of nonnasal stimuli repetition generally produced strongest relationships with perceptual ratings, with correlation values ranging from 0.49 to 0.70 (Watterson et al., 1996). Sweeney & Sell (2008) studied the relationships between perceptual judgments and nasalance scores for mixed sentences (0.74) but weak relationship (0.24) was reported by Watterson et al. (1993). Watterson et al.’s (1993; 1996) also concluded that nasal sentences are not suitable in identifying individuals who are hypernasal. These reports were in consistent with other studies (Dalston et al., 1991; Keuning et al., 2002; Sweeney et al., 2008) that have excluded nasally loaded stimuli altogether.

There are certain factors such as type of stimuli, perceptual rating scales and inclusionary criteria for the selection of the subjects that would have contributed to the variability in the correlation values (weak to moderate) between nasality and nasalance values. Individuals with VPD represent a highly heterogeneous group for instance, the severity of an individual's VPD may vary from a mild velopharyngeal dysfunction with perceptually normal resonance to a complete VPD resulting in severe hypernasality accompanied by nasal air emissions. Although studies in the literature did not control for nasal air emissions, certain literature suggests that mean nasalance scores may be affected (Karnell, 1995; Karnell, 2011). Karnell (1995) had argued that those with articulation errors should be excluded from studies such as these due to the potential increase in the nasalance values. The above inclusionary criteria were not were constantly monitored in the present study.

Finally, an additional area of disagreement when examining the nasalance/nasality relationship is the type of rating scale used during perceptual evaluations. Equal appearing interval scales and rating scales that use descriptive category judgments, (e.g., mild, moderate, and severe) are often used. However, the number of points in these scales have ranged from four to nine, or even 11 points (Whitehill, Francis, & Ching, 2003). A rating scale with a small range may lead to important perceptual information being overlooked, while a scale with a large range may take away from the judge's ability to focus on what they are hearing and select an accurate rating from multiple options. In the present study four point rating scales with descriptors were considered, which possibly might have increased the correlation and reliability values of the ratings done by the judges.

The correlation between nasalance values and velopharyngeal closure for vowels revealed a moderate to strong relationship for both pre and post-operative conditions. There was a high positive correlation between pre-operative recording of VPD rating for all the three vowels and their respective nasalance values. In the post-operative recordings, high vowels /i/ and /u/ had strong positive relationship between inadequate velopharyngeal closure and nasalance values. The results of the present study supports the findings of Kuehn and Moon (1998) who studied the velopharyngeal closure force in individuals with normal velopharyngeal mechanism for isolated vowels. The results revealed that VP control for vowels involved VP positioning different from that of either nasal or nonnasal conditions and these variations were specific to the language spoken by the individuals. The mean closure force for vowel production revealed that high vowels induced greater closure force than low vowels. These results suggested a relationship between the degree of VP closure force and velar height during vowel production. Because high vowels are produced with higher velar positions in comparison to low vowels, it is likely that the influence of tongue position on VP closure extends to adjacent speech sounds as well.

In contrast, there was a moderate positive relationship observed between post-operative nasalance values and perceptual rating of velopharyngeal closure dysfunction for vowel /a/. This may be due to the reason that complete velopharyngeal closure is not required to produce perceptually normal non-nasalized vowel /a/. Jones (1991) described that during the production of vowel /a/ the tongue is low in the oral cavity which creates low acoustic impedance to sound transmission in the oral cavity. If a velopharyngeal gap is present, it is more likely for the sound to transmit into the oral cavity due to lower acoustic impedance. The nasometric value does not indicate the cause for VPD, or the location and the size of the velopharyngeal gap. Contradictory results regarding the correlation between nasalance values and perceptual analysis have been reported. It has been suggested that the nasometer to be used as a supplement for perceptual judgement (Kummer, 2001).

CHAPTER V

SUMMARY AND CONCLUSIONS

The velopharyngeal dysfunction (VPD) is one of the common conditions occurring secondary to repaired cleft palate. Individuals with CLP often demonstrate multiple associated problems which are grouped under communicative and non-communicative problems. The communicative or speech related problems in individuals with CLP include hypernasality, hyponasality, nasal air emission, compensatory articulations, weak pressure consonants and unintelligible speech. Nasality is the common symptom that occurs due to velopharyngeal dysfunction in individuals with CLP. The management of VPD is grouped under surgical and non-surgical management. The success of the surgical intervention in VPD is evaluated through use of perceptual and instrumental assessment of speech characteristics.

The present study is aimed to investigate the speech characteristics of individuals with VPD before and after surgery. Thirty individuals with VPD with a mean age of 12.4 yrs and Kannada as their native language participated in the study. All the participants had a history of repaired cleft palate and diagnosed to have moderate to severe VPD using cineradiography procedure. The subjects were grouped into three subgroups based on surgical procedures used for management of VPD. The subgroups are namely secondary palatoplasty (n=18), pharyngoplasty (n=8) and combined surgery (n=4). The speech characteristics such as articulation, resonance, intelligiblity and voice were studied using perceptual and instrumental methods across pre, first post-operative (3 months follow up) and second post-operative (6 months follow up) conditions across different types of surgeries.

The perceptual evaluation of speech characteristics was carried out using universal parameters for reporting speech outcomes in individuals with VPD, a standardised rating scale based assessment protocol given by Henningsson et al. (2008). The instrumental assessment methods included nasometric, cineradiographic evaluation of VPD and calculation of DSI using Lingwaves software. The study was also aimed to find the correlation between subjective and objective assessment. The speech samples considered for the present study include isolated vowels (/a/, /i/ and /u/), three minute spontaneous speech sample on leisure / school activities, repetition of words loaded with pressure consonants , repetition of standardised oral and nasal sentences . These speech samples were audio - video recorded in a quiet room for both perceptual and instrumental evaluation of the speech characteristics in individuals with VPD. The speech samples were randomised across the conditions (pre, first and second follow up) and presented to three experienced judges (SLP's) for perceptual judgement who were also trained for judging the different speech parameters. The median perceptual scores were calculated for further analysis. Inter rater reliability was calculated for the entire speech samples and 25% of the speech samples were considered for intra judge reliability. Intra judge reliability was carried out one month after the first perceptual assessment.

The articulation errors were analysed perceptually and the mean percentage of articulation errors were calculated. The mean percentage of articulation errors were more in the pre-operative condition compared to post-operative follow up errors. Among the SODA articulation errors, substitution errors were reported to be more followed by distortion errors and omission errors across conditions. And on compensatory articulation error analysis, glottal stops and pharyngeal fricatives were found to be higher followed by pharyngeal stops. Fricatives and plosives were characterized by the weak production of consonants. Across types of surgery, pharyngoplasty had lesser overall articulation errors, SODA errors and compensatory errors followed by palatoplasty and combined surgery group. The palatoplasty group showed significant reduction in the articulation errors after surgical intervention in the post-operative conditions. The articulatory errors were also reduced after speech therapy.

The resonance characteristics were analysed quantitatively and qualitatively across conditions and surgery. The mean nasalance values were greater for vowels, syllables and sentences loaded with pressure consonants in the pre – operative condition. The nasalance values were reduced for the first and second follow up conditions. Among the vowels high front vowel /i/ had higher nasalance values followed by high back vowel /u/ and mid vowel /a/. The voiced CV syllables had greater nasalance values compared to voiceless CV syllables across conditions. Among the sentences, nasal sentences had greater nasalance values compared to oral sentences. Across conditions there was significant difference between pre and two post-operative condition for both palatoplasty and pharyngoplasty group. Across types of surgery, palatoplasty had significant outcomes followed by pharyngoplasty and combined surgery group.

The cineradiographic evaluation of velopharyngeal closure for vowels in the pre-operative condition showed that vowel /a/ had greater velopharyngeal opening followed by vowel /u/ and /i/. The velopharyngeal closure improved following surgical intervention which resulted in the reduced scores in the post-operative condition. For the palatoplasty group, across conditions there was a significant difference seen for vowel /a/ but not for other vowels. The perceptual assessment of nasality using a four point rating scale also revealed that hypernasality and nasal air emission had significantly reduced mean values in the post –operative conditions. For hyponasality the ratings showed no or very mild hyponasality which did not vary across conditions. The mean ratings for hypernasality and nasal air emission were found to be greater for spontaneous speech stimuli compare to sentences. Among the types of surgery palatoplasty and pharyngoplasty proved effective in reducing the hypernasality and nasal air emission.

The perceptual rating of speech understandability using a four point rating scale showed significant improvement in the post-operative condition. The results showed that there was a significant improvement in the post-operative scores of speech understandability for oral sentences. The percentage of speech intelligiblity calculated from the connected speech sample improved from 50 % to 77 % post operatively. Among the types of surgery, pharyngoplasty had significant impact on speech intelligiblity scores followed by combined surgery and palatoplasty.

The quantitative measurement of voice quality was assessed using dysphonia severity index, multiparametric assessment method. DSI was calculated for vowel /a/ across conditions and gender. The mean pre-operative DSI values (1.04 to 2.4) showed a moderate dysphonia and post operatively values ranged from (3.5 to 4.80) mild to normal voice quality. The results showed that DSI values were post operatively better compared to pre-operative conditions. Across gender, females were found to have better DSI values than male subjects. The individuals with VPD showed an increased jitter, reduced maximum pitch and lower intensity.

The relationship between instrumental and perceptual assessment of resonance characteristics was evaluated between nasalance values and perceptual measures of nasality across conditions. The pre-operative nasalance values for oral sentences had moderate correlation with pre-operative ratings of hypernasality and nasal air emission. But the first follow up results showed weak relationship between nasalance values and perceptual assessment. The association between nasalance values and perceptual ratings of VPD showed a strong relationship between velopharyngeal opening and nasalance values of vowels in the pre-operative condition. But for the post-operative condition a moderate relationship was seen between nasalance values and velopharyngeal opening during vowel production.

Overall the present study made an attempt to investigate the effect of surgery on speech characteristics of individuals with VPD. The comparison between pre and two post-operatives (3 months and 6 months follow up) across types of surgery was highlighted in this study. The results showed that speech characteristics improved after surgical intervention to some extent. Among the types of surgery, palatoplasty showed significant improvement followed by pharyngoplasty. The study also highlighted the improved articulation, resonance and speech intelligibility in individuals (n=15) who underwent speech therapy. This further advocates the need for intensive speech therapy in individuals with VPD. The present study revealed that both qualitative and quantitative analysis of speech characteristics for better profiling of speech outcomes in individuals with VPD. The study was carried out on small number of participants which restricts the generalization of the research findings. The participants could not be matched for gender and severity of VPD across types of surgery. Further research can be directed towards considering these aspects.

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APPENDIX A

I. Words loaded with pressure consonants in Kannada

Place of Articulation	Sounds	Words (Initial Position)	IPA	Words (Medial Position)	IPA
Labial	/p/	ಪಟ	/pɑṭɑ/	ಚಪಾತಿ	/tʃapɑ:t̪I/
	/b/	ಬಾಗಿಲು	/bɑ:gɪlu/	ತಬಲ	/t̪əbɑlɑ/
Labiodental	/v/	ವಡೆ	/vəḍe/	ಕಿವಿ	/kɪvɪ/
Dental	/ t̪ /	ತಾತ	/t̪ɑt̪ɑ/	ಕೋತಿ	/ko:t̪i/
	/d̪/	ದಾರ	/d̪ɑ:rɑ/	ಕುದುರೆ	/kud̪ʊre/
Retroflex	/ṭ/	ಟೋಪಿ	/ṭo:pɪ/	ಚಿಟ್ಟೆ	/tʃɪṭṭə/
	/ḍ/	ಡಬ್ಬಿ	/ḍəbbI/	ಕಡಪ	/kəḍɑpə/
Alveolar	/s/	ಸೇಬು	/se:bu/	ಮೀಸೆ	/mi:se/
Palatal	/ʧ/	ಚಪ್ಪಲಿ	/tʃəppəlɪ/	ವಾಚು	və:tʃʊ/
	/ ʤ /	ಜಡೆ	/dʒəḍe/	ಪೂಜಾರಿ	/pu:dʒɑ:rɪ/
	/ʃ/	ಶರ್ಟು	/ʃərṭʊ/	ಆಕಾಶ	/ɑ:kaʃɑ/
	/j/	ಯಮ	/jəmə/	ತೆಂಗಿನಕಾಯಿ	/t̪eṇgiṇɑkə:jɪ/
Velar	/k/	ಕಾಗೆ	/kɑ:gə/	ಬೆಕ್ಕು	/bekku/
	/g/	ಗಡಿಯಾರ	/gəḍij:rə/	ಟಗರು	/ṭəgarʊ/

II. Oral sentences

S.No	IPA	Kannada
1	ka:gƐ ka:lu kappu	ಕಾಗೆ ಕಾಲು ಕಪ್ಪು
2	git̪a bƐga: ho:gu	ಗೀತ ಬೇಗ ಹೋಗು
3	d̪ʌna d̪a:rI t̪apIt̪u	ದನ ದಾರಿ ತಪ್ಪಿತು
4	appa pat̥a: t̪a:	ಅಪ್ಪ ಪಟ ತಾ.
5	ba:lu t̪ʌbalʌ ba:rIsu	ಬಾಲು ತಬಲ ಬಾರಿಸು

III. Nasal sentences

S.No	IPA	Kannada
1	mʌnu a: nƐjannu no:dId̪a	ಮನು ಆನೆಯನ್ನು ನೋಡಿದ.
2	nʌvi:na mʌnƐjind̪a band̪ʌnu	ನವೀನ ಮನೆಯಿಂದ ಬಂದನು.
3	na:nu a: nƐjannu no:dId̪Ɛ	ನಾನು ಆನೆಯನ್ನು ನೋಡಿದೆ.
4	maŋga manƐja: mƐlId̪Ɛ	ಮಂಗ ಮನೆಯ ಮೇಲಿದೆ.
5	ma:ma mʌnd̥ja:d̪Ind̪a band̪ʌru	ಮಾಮ ಮಂಡ್ಯದಿಂದ ಬಂದರು

APPENDIX B

LIST OF TERMS [3]

1. Compensatory errors

Articulation gestures that are the individual's response to velopharyngeal dysfunction rather than the direct result of velopharyngeal dysfunction.

2. Glottal stops

A compensatory articulation production characterized by forceful adduction of the vocal folds and the build-up and release of air pressure under the glottis.

3. Hypernasality

A resonance disorder characterized by excessive resonance in the nasal cavities, often due to velopharyngeal dysfunction, particularly perceptible on vowel productions.

4. Hyponasality

A resonance disorder characterized by insufficient nasal resonance during speech, usually due to obstruction of the nasal tract.

5. Middorsum palatal stop

An abnormal articulation production that is produced by the middle of the dorsum articulating against the middle of the hard palate, also called a palatal dorsal production.

1. **Nasal air emission**

The sound of air forcefully flowing through the nose during speech due to poor valving between the oral and nasal cavities.

7. Nasalance

The ratio of nasal over nasal plus oral acoustic energy during speech as determined through the use of the Nasometer; represents the relative amount of nasal acoustic energy in the patient's speech.

8. Nasalization of oral phonemes

An obligatory error due to an open velopharyngeal port.

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[2] American Cleft palate – Craniofacial Association (2012, Januray 20). SLP cleft palate terminology. Retrieved from http://www.acpacpf.org/education/educational_resources/professional_enhancement_resources/slp_cleft_palate_terminology

9. Pharyngeal fricative

A compensatory articulation production while air escapes through a small opening between the base of the tongue and the posterior pharyngeal wall.

10. Pharyngeal stops

A compensatory articulation production that is produced by the base of the tongue articulating against the pharyngeal wall.

11. Pharyngoplasty

A surgical procedure of the pharynx that is designed to correct velopharyngeal dysfunction.

12. Posterior nasal fricative

An abnormal articulation production due to an audible friction sound of air escaping through a velopharyngeal opening.

13. Resonance

The quality of the voice that results from the vibration of sound in the pharynx, oral cavity, and nasal cavities.

14. Sphincter pharyngoplasty

A type of pharyngoplasty to create a dynamic sphincter that encircles the velopharyngeal port.

15. Submucous cleft palate

A type of cleft palate that is characterized by a midline deficiency in the bony structures of the hard palate or the muscles of the velum with intact oral surface by the covering of the mucous membrane.

16. Velar fricative:

A compensatory articulation production that is produced while air escapes through a small opening between the back of the tongue and the velum.

17. Velopharyngeal dysfunction (VPD)

A generic term used to describe velopharyngeal malfunction.

APPENDIX C

Severity Rating Scales and its corresponding Descriptors[4]

a) Hypernasality

Severity rating	Descriptors
0 = Within Normal Limits (WNL)	Nasality does not exceed the nasality heard in regional speech and there is no perceptual evidence of cleft type speech
1 = Mild	Nasality exceeds regional speech nasality There is increased nasality heard on high vowels primarily There is inconsistent or intermittent increase in nasality across vocalic segments Nasality is perceived as socially acceptable in most circles Parents are satisfied with individual's speech resonance Speech specialist probably wouldnot recommend physical management after instrumental assessment
2 = Moderate	Hypernasality is perceived as pervasive and draws attention to itself and away from the message There is increased nasality heard on high vowels and low vowels Most vowels retain their identity Speech is socially unacceptable Speech specialist probably would recommend physical management after instrumental assessment
3 = Severe	Hypernasality is perceived as pervasive and interferes with speech understandability There is increased nasality heard on vowels and some voiced consonants Some vowels may lose their identity Speech is socially very unacceptable Speech specialist definitely would recommend physical management after instrumental assessment

[3] Henningsson, G., Kuehn, D., Sell, D., Sweeney, T., Trost-Cardamone, J., & Whitehall, T. (2008). Universal parameters for reporting speech outcomes in individuals with cleft palate. *The Cleft Palate-Craniofacial Journal*, *45*(1), 1-17.

b) Hyponasality

Severity rating	Descriptors
0 = Within Normal Limits (WNL)	Nasality does not exceed the nasality heard in regional speech and there is no perceptual evidence of cleft type speech
1 = Mild	Evident but acceptable
2 = Moderate	Evident and inconsistent denasal production of consonant
3 = Severe	Total denasal production of nasal consonants

c) Nasal Air Emission

Severity rating	Descriptors
0 = Within Normal Limits (WNL)	Nasality does not exceed the nasality heard in regional speech and there is no perceptual evidence of cleft type speech
1 = Mild	Nasal air emission exceeds regional speech nasal emission.
2 = Moderate	Nasal air emission is perceived as pervasive and draws attention to itself and away from the message
3 = Severe	Nasal air emission is perceived as pervasive and interferes with speech understandability

d) Speech Understandability

Severity rating	Descriptors
0 = Within Normal Limits (WNL)	Speech is always easy to understand
1 = Mild	Speech is occasionally hard to understand
2 = Moderate	Speech is often hard to understand
3 = Severe	Speech is hard to understand most or all the time

e)Velopharyngeal Closure[5]

Severity rating	Descriptors
0 = Within Normal Limits (WNL)	Where the subject consistently achieves adequate closure
1 = Mild	Where the subject does not consistently achieves adequate closure
2 = Moderate	Where the subject closure is not consistently appropriate
3 = Severe	Where the subject closure is mostly inappropriate
4 = Very severe	Where the subject did not achieve any closure

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[5] Golding, K.J., Argamaso, R.V., Cotton, R.T., et al. (1990). Standardization for the Reporting of Nasopharyngoscopy and Multiview Videofluoroscopy: A report from an International Working Group. *Cleft Palate Journal*, *27*, 337-347.

APPENDIX D

CONSENT FORM

All India Institute of Speech & Hearing, Naimishm Campus
Manasagangothri, Mysore 570 006

Doctoral thesis
on
Effect of Surgery on Speech Characteristics in Individuals with Velopharyngeal Dysfunction: Pre-Post Operative Comparison

Information to the individuals / Parents

I, Mr.Gnanavel.K. have undertaken the research study entitled **"Effect of Surgery on Speech Characteristics in Individuals with Velopharyngeal Dysfunction: A Pre-Post-Operative Comparison"** under the guidance of Dr. M.Pushpavathi, Professor of Speech Pathology , Dept. of Speech – Language Pathology, AIISH, Mysore – 6. I request you to participate in the present study. . The research is aimed to compare the subtle changes in the speech characteristics (articulation , voice , resonance , speech understandability) before and after surgery. Information will be collected through audio visual recording of speech for the duration of 1hr each in three sittings. I assure you that this data will be kept confidential. Your cooperation in the study will go a long way in helping us in investigating the speech outcome following surgery in individuals with velopharyngeal dysfunction and giving more information about management programs for individuals with velopharyngeal impairments. I can assure you that this program will help individuals with velopharyngeal dysfunction and related disorders.

Informed Consent

I have been informed about the aims, objectives and the procedure of the study. The possible risks-benefits of my participation / my child's participation as human subject in the study are clearly understood by me. I understand that I have a right to refuse participation or withdraw my consent at any time. I have the freedom to write to head of the institute in case of any violation of these provisions without the danger of my being denied any rights to secure the clinical services at this institute. I am interested in participating in the study and hereby give my written consent for the same.

I, ______________________________________, the undersigned, give my consent to be participant of this investigation/study/program. I have no objection in participating in the program.

Signature of Research Participants
(Name and Address)

Signature of Investigator
Date

____

ಅಖಿಲ ಭಾರತ ವಾಕ್ ಶ್ರವಣ ಸಂಸ್ಥೆ, ನೈಮಿಷಂ ಆವರಣ, ಮಾನಸಗಂಗೋತ್ರಿ,
ಮೈಸೂರು – ೫೭೦೦೦೬

ವಿಷಯ: ಡಾಕ್ಟರೇಟ್ ಪದವಿ ಪೂರ್ವ ಸಂಶೋಧನೆ

ಸಂಶೋಧನೆಯ ವಿಷಯ: ಮೃದುತಾಳು-ಗಂಟಲಕುಳಿ ತೊಂದರೆಯ ಹೊಂದಿರುವವರಲ್ಲಿನ ಮಾತಿನ ಗುಣಲಕ್ಷಣಗಳು : ಶಸ್ತ್ರಚಿಕಿತ್ಸೆಯ ಮುಂಚಿನ ಹಾಗು ನಂತರದ ಹೋಲಿಕೆಗಳು

ಡಾಕ್ಟರೇಟ್ ಪದವಿ ಪೂರ್ವ ಸಂಶೋಧನಾ ವಿದ್ಯಾರ್ಥಿಯಾದ ನಾನು- ಶ್ರೀ ಜ್ಞಾನವೇಲ್ . ಕೆ ಈ ಮೇಲ್ಕಂಡ ವಿಷಯದಲ್ಲಿ ಸಂಶೋಧನೆ ಮಾಡಬೇಕೆಂದಿದ್ದೇನೆ. ಈ ಸಂಶೋಧನೆಯನ್ನು ಡಾ|| ಎಂ. ಪುಷ್ಪಾವತಿ , ಪ್ರಾಧ್ಯಾಪಕರು (ವಾಕ್ ಮತ್ತು ಭಾಷಾ ರೋಗಲಕ್ಷಣಗಳ ವಿಭಾಗ) ಅವರ ನೇತೃತ್ವದಲ್ಲಿ ಮಾಡುತ್ತಿದ್ದೇನೆ. ಈ ಸಂಶೋಧನೆಯಲ್ಲಿ ತಾವು ಭಾಗವಹಿಸಬೇಕೆಂದು ಕೋರಿಕೊಳ್ಳುತ್ತೇನೆ. ಸಂಶೋಧನೆಗೆ ಬೇಕಾದ ಮಾಹಿತಿಗಳನ್ನು ಧ್ವನಿ ಮತ್ತು ವಿಡಿಯೋ ಚಿತ್ರೀಕರಣದ (ಆಡಿಯೋ ಮತ್ತು ವೀಡಿಯೊ ರೆಕಾರ್ಡಿಂಗ್) ಮೂಲಕ ಸಂಗ್ರಹಿಸಲಾಗುತ್ತದೆ. ಈ ಕಾರ್ಯಕ್ಕೆ ಸಂಶೋಧನೆಯಲ್ಲಿ ಭಾಗವಹಿಸುವ ಮಕ್ಕಳ ಜೊತೆ ಸುಮಾರು ಒಂದು ಗಂಟೆಯ ಸಂದರ್ಶನದ ಅವಶ್ಯಕತೆ ಇದೆ. ಪೂರ್ಣ ಮಾಹಿತಿ ಸಂಗ್ರಹಿಸಲು ಈ ತರಹದ ಮೂರು ಸಂದರ್ಶನದ ಅವಶ್ಯಕತೆ ಇರುತ್ತದೆ. ಈ ಮಾಹಿತಿಗಳನ್ನೆಲ್ಲಾ ಗೌಪ್ಯವಾಗಿ (Confidential) ಇಡಲಾಗುತ್ತದೆ ಎಂದು ಭರವಸೆ ನೀಡುತ್ತೇನೆ. ಈ ಸಂಶೋಧನೆಯಿಂದ ನಮಗೆ ಸೀಳು ಅಂಗುಳ ಇರುವ ಮಕ್ಕಳ ಮಾತಿನ ನ್ಯೂನತೆಗಳನ್ನು ಪತ್ತೆಹಚ್ಚಬಹುದು. ಇದರಿಂದ ಇಂತಹ ಮಕ್ಕಳ ಪುನರ್ವಸತಿ/ ತರಬೇತಿಯ ವಿಧಾನವನ್ನು ನಿರ್ಧರಿಸುವ ಬಗ್ಗೆ ಮಾಹಿತಿ ದೊರೆಯುತ್ತದೆ. ಆದ್ದರಿಂದ ಈ ಸಂಶೋಧನೆಯಿಂದ ಸೀಳು ಅಂಗುಳ ಇರುವ ಮಕ್ಕಳಿಗೆ ಬಹಳ ಉಪಯೋಗವಾಗುತ್ತದೆ. ಇದಕ್ಕಾಗಿ ಸಹಕರಿಸಬೇಕಾಗಿ ವಿನಂತಿ.

ಸಮ್ಮತಿ ಪತ್ರ

ಈ ಸಂಶೋಧನೆಯ ಬಗ್ಗೆ ಅಂದರೆ, ಅದರ ಗುರಿ ಹಾಗು ಮಾಹಿತಿ ಸಂಗ್ರಹಿಸುವ ವಿಧಾನದ ಬಗ್ಗೆ ನನಗೆ ಪೂರ್ಣ ತಿಳುವಿಕೆ ಲಭಿಸಿದೆ. ಈ ಸಂಶೋಧನೆಯಲ್ಲಿ ಭಾಗವಹಿಸುವಾಗ ಉಂಟಾಗುವ ಅಡತಡೆ / ತೊಂದರೆಗಳ ಬಗ್ಗೆಯೂ ನನಗೆ ಅರಿವಿಕೆ / ಅರ್ಥವಾಗಿದೆ. ಈ ಸಂಶೋಧನೆಯಲ್ಲಿ ಭಾಗವಹಿಸುವುದನ್ನು ಯಾವಾಗ ಬೇಕಾದರೂ ನಿರಾಕರಿಸುವ ಸಂಪೂರ್ಣ ಹಕ್ಕನು ನಾನು ಪಡೆದಿರುತ್ತೇನೆ. ಈ ಮೇಲ್ಕಂಡ ಸಂಶೋಧನೆಯಲ್ಲಿ ಹೇಳಿರುವಂತಹ ಕಾರ್ಯಗಳಲ್ಲಿ/ ವಿಧಾನಗಳಲ್ಲಿ ಏನಾದರೂ ನಿಯಮದ ಉಲಂಘನೆಯಾದಲ್ಲಿ ಎ.ಇ.ಸಿ ಚೇರ್ ಮೆನ್ (AEC Chairman) ರನ್ನು ಸಂಪರ್ಕಿಸುವ ಸ್ವಾತಂತ್ರ್ಯಾ ನನಗಿದೆ. ಇದರಿಂದಾಗಿ ಮೇಲ್ಕಂಡ ಸಂಸ್ಥೆಯವರು ನನಗೆ ಅಲ್ಲಿ ಸಿಗುವಂತಹ ಚಿಕಿತ್ಸಾ ಸೌಲಭ್ಯಗಳನ್ನು ನಿರಾಕರಿಸಲು ಸಾಧ್ಯವಿಲ್ಲ. ನನಗೆ ಈ ಸಂಶೋಧನೆಯಲ್ಲಿ ಭಾಗವಹಿಸಲು ಸಮ್ಮತಿ ಇದೆ. ಈ ಸಮ್ಮತಿಯನ್ನು ಬರವಣಿಗೆಯಲ್ಲಿ ಕೊಡುತ್ತಿದ್ದೇನೆ.

ನಾನು ______________________________ , ಈ ಮೇಲ್ಕಂಡ ಕಾರ್ಯಕ್ರಮದಲ್ಲಿ/ ಸಂಶೋಧನೆಯಲ್ಲಿ ಭಾಗವಹಿಸಲು ಸಂಪೂರ್ಣ ಸಮ್ಮತಿ ನೀಡುತ್ತೇನೆ. ಈ ಕೆಳಕಂಡಂತೆ ಸಹಿ ಹಾಕಿರುತ್ತೇನೆ.

ವ್ಯಕ್ತಿಯ ಸಹಿ — ಸಂಶೋಧಕರ ಸಹಿ

(ಹೆಸರು ಮತ್ತು ವಿಳಾಸ) — ದಿನಾಂಕ:

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APPENDIX E

1. Mean , S.D and Median for Nasalance values of unvoiced CV syllables in the context of vowel /i/ in children

CV Syllables	Types of Surgery	Nasalance values (%)											
		Condition I				Condition II				Condition III			
		N	*M*	*SD*	*Mdn*	*N*	*M*	*SD*	*Mdn*	N	*M*	*SD*	*Mdn*
/pi/	G I	17	63.52	15.10	67.00	17	54.88	12.83	58.00	9	57.22	12.94	60.00
	G II	3	68.66	4.16	70.00	3	51.33	12.05	50.00	2	47.00	24.04	47.00
	G III	2	44.50	10.60	44.50	2	71.00	18.38	71.00	1	58.00*	-	58.00
	Total	22	62.50	14.76	66.50	22	55.86	13.45	58.00	12	55.58	13.80	59.00
/ti/	G I	17	65.88	11.53	68.00	17	56.35	10.41	54.00	9	56.44	14.74	62.00
	G II	3	69.00	2.64	68.00	3	53.66	7.23	50.00	2	47.00	2.82	47.00
	G III	2	71.00	19.79	71.00	2	68.50	13.43	68.50	1	60.00*	-	60.00
	Total	22	66.77	11.12	68.00	22	57.02	10.52	64.50	12	55.16	13.21	56.50
/ki/	G I	17	67.76	13.36	67.00	17	59.47	12.36	58.00	9	62.33	14.89	70.00
	G II	3	73.66	5.03	73.00	3	50.00	11.13	48.00	2	48.00	25.45	48.00
	G III	2	75.00	16.97	75.00	2	76.50	7.77	76.50	1	82.00*	-	82.00
	Total	22	69.22	12.64	69.50	22	59.72	13.10	59.00	12	61.58	17.09	68.00

Note. [M= Mean, SD = standard deviation, Mdn = Median, Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up, * = Single subject's data, - = No standard deviation]

2. Mean , S.D and Median for Nasalance values of unvoiced CV syllables in the context of vowel /i/ in adults

CV Syllables	Type of Surgery (N)	*N*	Condition I *M*	Condition I *SD*	Condition I *Mdn*	*N*	Condition II *M*	Condition II *SD*	Condition II *Mdn*	N	Condition III *M*	Condition III *SD*	Condition III *Mdn*
/pi/	G I	1	76.00*	-	76.00	1	74.00*	-	74.00	1	40.00*	-	40.00
	G II	5	74.20	15.29	74.00	5	58.40	22.42	60.00	2	53.00	26.87	53.00
	G III	2	59.00	5.64	59.00	2	54.00	8.48	54.00	-	-	-	-
	Total	8	69.50	13.48	73.50	8	59.25	18.35	60.00	3	48.66	20.42	40.00
/ti/	G I	1	74.00*	-	74.00	1	70.00*	-	70.00	1	50.00*	-	50.00
	G II	5	77.25	15.35	76.00	5	59.00	20.03	64.00	2	51.00	32.52	51.00
	G III	2	65.00	1.41	65.00	2	60.00	7.07	60.00	-	-	-	-
	Total	8	73.75	12.89	75.00	8	60.62	15.84	64.00	3	50.66	23.00	50.00
/ki/	G I	1	71.00*	-	71.00	1	70.00*	-	70.00	1	55.00*	-	55.00
	G II	5	77.00	13.92	81.00	5	61.40	21.23	54.00	2	58.00	32.52	58.00
	G III	2	67.00	4.24	67.00	2	62.50	7.77	62.50	-	-	-	-
	Total	8	73.75	11.62	70.50	8	62.75	16.50	62.50	3	57.00	23.05	55.00

Note. [M= Mean, SD = standard deviation, Mdn = Median, Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up, * - Single subject's data, - = No data / No Standard deviation]

3. **Mean , S.D and Median for Nasalance values of unvoiced CV syllables in the context of vowel /u/ in children**

CV Syllables	Types of Surgery (N)	Nasalance values (%)											
		Condition I				Condition II				Condition III			
		N	***M***	***SD***	***Mdn***	***N***	***M***	***SD***	***Mdn***	**N**	***M***	***SD***	***Mdn***
/pu/	G I	17	55.11	15.09	58.00	17	44.00	12.71	47.00	9	50.00	12.16	52.00
	G II	3	57.00	1.00	57.00	3	52.66	2.51	53.00	2	40.50	10.60	40.50
	G III	2	65.50	28.99	65.50	2	59.50	21.92	59.50	1	50.00*	-	50.00
	Total	22	56.31	14.92	58.00	22	46.59	13.16	49.50	12	48.41	11.46	49.00
/tu/	G I	17	56.00	14.58	57.00	17	44.11	12.11	45.00	9	46.44	14.64	52.00
	G II	3	53.33	4.04	51.00	3	35.66	8.14	32.00	2	31.00	1.14	31.00
	G III	2	59.00	25.45	59.00	2	57.00	8.48.	57.00	1	40.00*	-	40.00
	Total	22	55.90	14.00	56.00	22	44.13	12.15	45.00	12	43.33	13.88	45.00
/ku/	G I	17	53.47	12.44	52.00	17	41.29	8.60	40.00	9	47.22	15.84	48.00
	G II	3	58.00	2.66	59.00	3	52.66	4.61	50.00	2	51.50	2.12	51.50
	G III	2	56.50	26.16	56.50	2	57.00	21.12	57.00	1	48.00*	-	48.00
	Total	22	54.36	12.41	53.50	22	44.27	10.60	43.00	12	48.00	13.62	49.00

Note. [M= Mean, SD = standard deviation, Mdn = Median, Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up, * = Single subject's data, - = No standard deviation]

4. **Mean , S.D and Median for Nasalance values of unvoiced CV syllables in the context of /u/ vowel in adults**

CV Syllables	Type of Surgery (N)	Nasalance values (%)											
		Condition I				Condition II				Condition III			
		N	***M***	***SD***	***Mdn***	***N***	***M***	***SD***	***Mdn***	**N**	***M***	***SD***	***Mdn***
/pu/	G I	1	66.00*	-	66.00	1	39.00*	-	39.00	1	33.00*	-	33.00
	G II	5	55.00	21.31	55.00	5	44.20	17.34	44.00	2	47.50	10.60	47.50
	G III	2	48.00	24.04	48.00	2	35.00	7.07	35.00	-	-	-	-
	Total	8	54.62	19.32	56.50	8	41.25	14.03	41.50	3	42.66	11.23	40.00
/tu/	G I	1	57.00*	-	57.00	1	45.00*	-	45.00	1	30.00*	-	30.00
	G II	5	57.20	26.37	52.00	5	47.8	21.21	40.00	2	37.50	17.67	37.50
	G III	2	37.00	15.55	37.00	2	34.50	14.84	34.50	-	-	-	-
	Total	8	52.12	22.78	50.00	8	44.12	18.02	42.50	3	35.00	13.22	30.00
/ku/	G I	1	53.00*	-	53.00	1	45.00*	-	45.00	1	30.00*	-	30.00
	G II	5	51.80	18.92	51.00	5	44.60	19.62	43.00	2	43.50	19.09	43.50
	G III	2	37.50	2.12	37.50	2	32.50	3.53	32.50	-	-	-	-
	Total	8	48.37	15.82	45.00	8	41.62	15.92	39.00	3	39.00	15.58	30.00

Note. [M= Mean, SD = standard deviation, Mdn = Median, Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up, * = Single subject's data, - = No data / No Standard deviation]

5. Mean , S.D and Median for Nasalance values of voiced CV syllables in the context of vowel /i/ in children

CV Syllables	Types of Surgery	Nasalance values (%)											
		Condition I				Condition II				Condition III			
		N	*M*	*SD*	*Mdn*	*N*	*M*	*SD*	*Mdn*	N	*M*	*SD*	*Mdn*
/bi/	G I	17	67.05	10.01	67.00	17	59.47	10.49	60.00	9	62.11	9.33	59.00
	G II	3	72.00	6.55	73.00	3	50.66	15.94	43.00	2	53.50	19.09	53.50
	G III	2	65.50	19.09	65.50	2	69.50	20.50	69.50	1	61.00*	-	61.00
	Total	22	67.59	10.06	67.50	22	59.18	12.19	59.50	12	60.58	10.37	59.50
/di/	G I	17	67.35	11.81	69.00	17	57.76	10.54	56.00	9	58.11	13.42	58.00
	G II	3	79.33	7.09	78.00	3	67.00	6.08	64.00	2	65.50	6.86	65.50
	G III	2	70.00	9.81	70.00	2	68.50	13.43	68.50	1	66.00*	-	66.00
	Total	22	69.22	1.54	71.00	22	60.00	10.71	58.50	12	60.00	12.09	62.00
/gi/	G I	17	73.00	7.11	73.00	17	62.92	8.26	60.00	9	60.22	8.10	60.00
	G II	3	76.66	2.08	76.00	3	61.66	7.63	60.00	2	53.50	4.94	53.50
	G III	2	71.50	3.53	71.50	2	77.00	11.31	77.00	1	53.00*	-	53.00
	Total	22	73.36	6.44	73.50	22	64.04	9.02	61.50	12	58.50	7.72	56.00

Note. [M= Mean, SD = standard deviation, Mdn =Median, Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up, * - Single subject's data, - = No standard deviation]

6. Mean, S.D and Median for Nasalance values of voiced CV syllables in the context of vowel /i/ in adults.

CV Syllables	Type of Surgery (N)	Nasalance values (%)											
			Condition I				Condition II				Condition III		
		N	***M***	***SD***	***Mdn***	***N***	***M***	***SD***	***Mdn***	**N**	***M***	***SD***	***Mdn***
/bi/	G I	1	64.00*	-	64.00	1	70.00*	-	70.00	1	55.00*	-	55.00
	G II	5	69.20	14.58	73.00	5	60.00	17.01	59.00	2	58.50	4.94	58.50
	G III	2	66.50	2.12	66.50	2	60.00	7.07	60.00	-	-	-	-
	Total	8	69.00	11.23	70.50	8	61.62	13.91	60.50	3	60.33	4.72	62.00
/di/	G I	1	74.00*	-	74.00	1	72.00*	-	72.00	1	50.00*	-	50.00
	G II	5	71.40	15.24	76.00	5	58.20	20.82	59.00	2	63.00	11.31	63.00
	G III	2	74.50	7.77	74.50	2	57.50	24.74	57.50	-	-	-	-
	Total	8	72.50	11.98	75.00	8	59.75	18.97	61.00	3	58.66	10.96	55.00
/gi/	G I	1	70.00*	-	70.00	1	75.00*	-	75.00	1	70.00*	-	70.00
	G II	5	74.20	22.48	80.00	5	64.00	24.81	68.00	2	63.00	11.31	63.00
	G III	2	89.00	12.72	89.00	2	65.00	14.14	65.00	-	-	-	-
	Total	8	77.37	19.12	80.00	8	65.62	19.87	71.50	3	65.33	8.96	70.00

Note. [M= Mean, SD= standard deviation, Mdn= Median, Group I (GI) = Palatoplasty, Group II (GII) =Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up, * = Single subject's data, - = No data / No Standard deviation]

7. Mean , S.D and Median for Nasalance values of voiced CV syllables in the context of vowel /u/ in children

CV Syllables	Types of Surgery (N)	Nasalance values (%)											
		Condition I				Condition II				Condition III			
		N	***M***	***SD***	***Mdn***	***N***	***M***	***SD***	***Mdn***	**N**	***M***	***SD***	***Mdn***
/bu/	G I	17	58.52	11.86	59.00	17	50.64	9.08	52.00	9	49.00	17.20	48.00
	G II	3	64.33	4.72	66.00	3	50.33	5.50	50.00	2	54.55	13.43	54.50
	G III	2	59.50	10.60	59.50	2	54.50	13.43	54.50	1	47.00*	-	47.00
	Total	22	59.40	10.90	59.50	22	50.95	8.70	52.00	12	49.83	15.39	48.00
/du/	G I	17	60.88	11.07	64.00	17	50.82	10.33	50.00	9	53.33	15.65	56.00
	G II	3	62.66	4.16	64.00	3	52.33	5.85	50.00	2	53.50	12.02	53.50
	G III	2	54.00	8.48	54.00	2	55.50	16.40	55.50	1	61.00*	-	61.00
	Total	22	60.50	10.16	62.00	22	51.45	10.40	50.00	12	54.00	14.00	57.00
/gu/	G I	17	60.17	13.22	61.00	17	49.41	9.57	53.00	9	52.31	16.10	55.00
	G II	3	63.66	8.50	64.00	3	54.00	6.55	55.00	2	55.00	0.00	55.00
	G III	2	64.00	19.79	64.00	2	63.00	11.31	63.00	1	62.00*	-	62.00
	Total	22	61.00	12.70	61.50	22	51.27	9.83	54.00	12	53.58	14.02	55.00

Note. [M= Mean, SD = standard deviation, Mdn = Median, Group I (GI) = Palatoplasty, Group II (GII) –Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up, * = Single subject's data, - = No standard deviation]

8. Mean , S.D and Median for Nasalance values of voiced CV syllables in the context of /u/ vowel in adults

CV Syllables	Type of Surgery (N)	*N*	Condition I *M*	Condition I *SD*	Condition I *Mdn*	*N*	Condition II *M*	Condition II *SD*	Condition II *Mdn*	N	Condition III *M*	Condition III *SD*	Condition III *Mdn*
/pu/	G I	1	70.00*	-	70.00	1	55.00*	-	55.00	1	50.00*	-	50.00
	G II	5	57.60	17.08	57.00	5	44.20	16.85	42.00	2	40.50	0.70	40.50
	G III	2	36.00	4.62	36.00	2	30.00	0.00	30.00	-	-	-	-
	Total	8	53.75	17.53	54.00	8	42.00	15.20	36.00	3	43.66	5.50	41.00
/tu/	G I	1	65.00*	-	65.00	1	53.00	-	53.00	1	48.00*	-	48.00
	G II	5	55.80	19.79	55.00	5	43.60	21.89	35.00	2	39.50	13.43	39.50
	G III	2	43.00	2.82	43.00	2	40.00	0.00	40.00	-	-	-	-
	Total	8	53.75	16.70	50.00	8	43.87	17.03	40.00	3	42.33	10.69	48.00
/ku/	G I	1	50.00*	-	50.00	1	78.00*	-	78.00	1	75.00*	-	75.00
	G II	5	64.00	11.95	63.00	5	50.00	17.24	44.00	2	49.50	6.36	49.50
	G III	2	89.00	12.72	89.00	2	65.00	14.14	65.00	-	-	-	-
	Total	8	77.37	19.12	80.00	8	65.62	19.87	71.50	3	65.33	8.96	70.00

Note. [M= Mean, SD = Standard deviation, Mdn = Median, Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up, * = Single subject's data, - = No data / No Standard deviation]

9. Mean, Standard Deviation and Median for MPT in Children.

Age	Type of Surgery (N)	Maximum Phonation Time (MPT) sec											
		Condition I				Condition II				Condition III			
		N	***M***	***SD***	***Mdn***	***N***	***M***	***SD***	***Mdn***	**N**	***M***	***SD***	***Mdn***
Males (n=12)	G I	11	11.90	2.21	11.00	11	12.45	3.01	12.00	7	13.85	1.95	14.00
	G II	1	10.00*	-	10.00	1	12.00*	-	12.00	-	-	-	-
	G III	-	-	-	-	-	-	-	-	-	-	-	-
	Total	12	11.75	2.17	11.00	12	12.41	12.00	2.87	7	13.85	1.95	14.00
Females (n=10)	G I	6	10.33	2.73	9.50	6	10.33	2.87	9.50	2	11.50	3.53	11.50
	G II	2	13.00	1.41	13.00	2	12.50	2.12	12.50	2	14.00	1.41	14.00
	G III	2	16.00	2.82	16.00	2	16.50	2.12	16.5	1	16.00*	-	16.00
	Total	10	16.00	1.00	16.00	10	16.00	4.00	16.00	5	13.40	2.70	14.00

Note. [M= Mean, SD = Standard deviation, Mdn = Median, Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up, * = Single subject’s data, - = No data / No Standard deviation]

10. Mean, Standard Deviation and Median for MPT in Adults.

Age	Type of Surgery (N)	Maximum Phonation Time (MPT) sec											
		Condition I				Condition II				Condition III			
		N	***M***	***SD***	***Mdn***	***N***	***M***	***SD***	***Mdn***	**N**	***M***	***SD***	***Mdn***
Males	G I	1	13.00*	-	13.00	1	15.00*	-	15.00	1	16.00*	-	16.00
(n=5)	G II	3	18.00	1.00	18.00	3	18.00	2.00	18.00	1	19.00*	-	19.00
	G III	1	18.00*	-	18.00	1	18.00*	-	18.00	-	-	-	-
	Total	5	17.00	2.34	18.00	5	17.40	1.94	18.00	2	17.50	2.12	17.50
	G I	-	-	-	-	-	-	-	-	-	-	-	-
Females	G II	2	15.50	0.70	15.50	2	14.00	2.82	14.00	1	14.00*	-	14.00
(n=3)	G III	1	17.00*	-	17.00	1	20.00*	-	20.00	-	-	-	-
	Total	3	16.00	1.00	16.00	3	16.00	4.00	16.00	1	14.00*	-	14.00

Note. [M= Mean, SD = Standard deviation, Mdn = Median, Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up, * = Single subject’s data, - = No data / No Standard deviation]

11. Mean, Standard Deviation and Median for Highest Fundamental Frequency in Children

Age	Type of Surgery	Highest Fundamental Frequency (Fo High) in HZ											
		Condition I				Condition II				Condition III			
		N	*M*	*SD*	*Mdn*	N	*M*	*SD*	*Mdn*	*N*	*M*	*SD*	*Mdn*
Males (n=12)	C I	11	631.00	17.17	630.74	11	641.49	14.78	640.08	7	639.85	12.78	649.00
	C II	1	700.00*	-	700.00	1	740.00*	-	740.00	-	-	-	-
	C III	-	-	-	-	-	-	-	-	-	-	-	-
	Total	12	636.75	26.11	630.74	12	649.70	31.73	643.03	7	639.85	12.78	649.00
Females (n=10)	C I	6	740.35	22.01	731.06	6	740.80	12.22	740.40	2	742.00	16.97	743.00
	C II	2	757.83	11.08	757.83	2	764.51	7.75	764.51	2	750.00	14.14	750.00
	C III	2	765.00	7.67	765.00	2	751.00	4.64	751.00	1	760.00*	-	760.00
	Total	10	748.78	20.36	755.00	10	747.58	13.73	748.17	5	748.80	13.31	754.00

Note. [M= Mean, SD = Standard deviation, Mdn = Median, Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up, * = Single subject's data, - = No data / No Standard deviation]

12. Mean, Standard Deviation and Median for Highest Fundamental Frequency in Adults

Age	**Type of Surgery**	**Highest Fundamental Frequency (Fo High) in HZ**											
		Condition I				**Condition II**				**Condition III**			
		N	***M***	***SD***	***Mdn***	**N**	***M***	***SD***	***Mdn***	***N***	***M***	***SD***	***Mdn***
Males (n=5)	C I	1	600.00*	-	600.00	1	650.00*	-	650.00	1	660.00*	-	660.00
	C II	3	700.00	52.51	720.00	3	675.40	65.69	650.00	1	720.00*	-	720.00
	C III	1	619.20*	-	619.20	1	635.70*	-	635.70	-	-	-	-
	Total	5	663.90	62.36	640.70	5	662.38	50.01	650.01	2	690.00	42.42	690.00
Females (n=3)	C I	-	-	-	-	-	-	-	-	-	-	-	-
	C II	2	745.00	15.55	745.00	2	731.80	16.68	731.80	1	700.00*	-	700.00
	C III	1	752.50*	-	752.50	1	760.54*	-	760.54	-	-	-	-
	Total	3	747.50	11.82	752.50	3	747.58	13.73	748.17	1	748.80*	13.31	754.00

Note. [M= Mean, SD = Standard deviation, Mdn = Median, Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up, * = Single subject's data, - = No data / No Standard deviation]

13. Mean, Standard Deviation and Median for Lowest Intensity (Ilow, dB) in Children.

Age	Type of Surgery (N)	Lowest Intensity (Ilow, dB)											
		Condition I				Condition II				Condition III			
		N	*M*	*SD*	*Mdn*	*N*	*M*	*SD*	*Mdn*	N	*M*	*SD*	*Mdn*
Males (n=12)	G I	11	54.51	3.49	55.32	11	53.71	2.84	53.28	7	52.71	1.88	52.00
	G II	1	58.00*	-	58.00	1	52.00*	-	52.00	-	-	-	-
	G III	-	-	-	-	-	-	-	-	-	-	-	-
	Total	12	54.80	3.48	55.66	12	53.56	2.75	53.14	7	52.71	1.88	52.00
Females (n=10)	G I	6	56.16	2.63	56.50	6	53.58	2.87	53.75	2	54.00	2.80	54.00
	G II	2	58.00	1.41	58.00	2	54.50	0.70	54.50	2	54.50	3.43	54.50
	G III	2	57.50	0.70	57.50	2	53.00	1.41	53.00	1	54.00*	-	54.00
	Total	10	56.80	2.20	57.00	10	53.65	2.26	54.00	5	54.20	2.28	54.00

Note. [M= Mean, SD = Standard deviation, Mdn = Median, Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up, * = Single subject's data, - = No data / No Standard deviation]

14. Mean, Standard Deviation and Median for Lowest Intensity (Ilow, dB) in Adults.

Age	Type of Surgery (N)	Lowest Intensity (Ilow, dB)											
		Condition I				Condition II				Condition III			
		N	***M***	***SD***	***Mdn***	***N***	***M***	***SD***	***Mdn***	**N**	***M***	***SD***	***Mdn***
Males	G I	1	59.00*	-	59.00	1	53.00*	-	53.00	1	54.00*	-	54.00
(n=5)	G II	3	54.00	1.73	55.00	3	55.00	1.00	55.00	1	53.00*	-	53.00
	G III	1	51.00*	-	51.00	1	51.00*	-	51.00	-	-	-	-
	Total	5	54.40	3.13	55.00	5	53.80	1.92	54.00	2	53.50	0.70	53.50
	G I	-	-	-	-	-	-	-	-	-	-	-	-
Females	G II	2	54.00	4.24	54.00	2	54.00	1.41	54.00	1	56.00*	-	56.00
(n=3)	G III	1	53.00*	-	53.00	1	50.00*	-	50.00	-	-	-	-
	Total	3	53.66	3.05	53.00	3	52.66	2.51	53.00	1	56.00*	-	56.00

Note. [M= Mean, SD = Standard deviation, Mdn = Median, Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up, * = Single subject's data, - = No data / No Standard deviation]

15. Mean, Standard Deviation and Median for Jitter (%) in Children.

Age	Type of Surgery (N)	Jitter (%)											
		Condition I				Condition II				Condition III			
		N	***M***	***SD***	***Mdn***	***N***	***M***	***SD***	***Mdn***	**N**	***M***	***SD***	***Mdn***
Males	G I	11	1.21	0.64	1.41	11	0.59	0.56	0.47	7	0.76	0.52	0.50
(n=12)	G II	1	1.00*	-	1.00	1	0.40*	-	0.40	-	-	-	-
	G III	-	-	-	-	-	-	-	-	-	-	-	-
	Total	12	1.19	0.62	1.07	12	0.57	0.43	0.54	7	0.76	0.52	0.50
	G I	6	0.47	0.48	0.31	6	0.51	0.25	0.40	2	0.40	0.00	0.40
Females	G II	2	0.51	0.40	0.51	2	0.93	0.08	0.93	2	0.80	1.41	0.80
(n=10)	G III	2	0.99	0.01	0.99	2	0.78	0.16	0.78	1	0.70*	-	0.70
	Total	10	0.58	0.44	0.41	10	0.65	0.27	0.63	5	0.62	0.20	0.70

Note. [M= Mean, SD = Standard deviation, Mdn = Median, Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up, * = Single subject's data, - = No data / No Standard deviation]

16. Mean, Standard Deviation and Median for Jitter (%) in Adults.

Age	Type of Surgery (N)	Jitter (%)											
		Condition I				Condition II				Condition III			
		N	***M***	***SD***	***Mdn***	***N***	***M***	***SD***	***Mdn***	**N**	***M***	***SD***	***Mdn***
Males	G I	1	0.70*	-	0.70	1	0.80*	-	0.80	1	0.40*	-	0.40
(n=5)	G II	3	1.33	0.49	1.10	3	0.85	0.38	0.78	1	0.60*	-	0.60
	G III	1	1.27*	-	1.27	1	0.10*	-	0.10	-	-	-	-
	Total	5	1.19	0.44	1.10	5	0.69	0.43	0.79	2	0.50	0.14	0.50
	G I	-	-	-	-	-	-	-	-	-	-	-	-
Females	G II	2	0.98	0.36	0.98	2	0.84	0.06	0.84	1	0.90*	-	0.90
(n=3)	G III	1	1.20*	-	1.20	1	0.86*	-	0.86	-	-	-	-
	Total	3	1.05	0.28	1.20	3	0.85	0.04	0.86	1	0.90*	-	0.90

Note. [M= Mean, SD= Standard deviation, Mdn = Median, Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up, * = Single subject's data, - = No data / No Standard deviation]

17. Individual data for compensatory articulatory errors (backing errors) in individuals with VPD

Groups	Sub. No	Backing Errors to Oral to Post Uvular Place (%)									Backing Errors to Oral Place (%)					
		Glottal Stops			Pharyngeal Stops			Pharyngeal Fricatives			Palatal stops			Velar stops		
		CI	C II	C III	C I	CII	C III	C I	C II	C III	CI	CII	CIII	C I	C II	C III
	1	-	-	-	-	-	-	15.00	10.00	-	-	-	-	5.00	-	-
	2	10.00	10.00	5.00	15.00	10.00	10.00	15.00	10.00	10.00	-	-	-	-	-	-
	3	5.00	5.00	-	-	-	-	-	-	-	-	-	-	10.00	10.00	
	4	5.00	.00	-	-	-	-	10.00	10.00	5.00	-	-	-	-	-	-
	5	10.00	5.00	5.00	-	-	-	10.00	10.00	5.00	-	-	-	-	-	-
Group I	6	15.00	10.00	10.00	10.00	10.00	5.00	-	-	-	-	-	-	-	-	-
	7	10.00	10.00	5.00	10.00	10.00	5.00	-	-	-	-	-	-	15.00	15.00	10.00
	8	15.00	5.00	-	10.00	10.00	-	-	-	-	-	-	-	5.00	5.00	-
	9	-	-	-	-	-	-	10.00	5.00	-	10.00	5.00	-	-	-	-
	10	10.00	10.00	-	15.00	15.00	-	-	-	-	15.00	15.00	-	-	-	-
	11	15.00	10.00	-	5.00	5.00	-	5.00	5.00	-	-	-	-	-	-	-
	12	20.00	20.00	-	-	-	-	10.00	10.00	-	-	-	-	-	-	-
	13	-	-	-	5.00	5.00	-	-	-	-	-	-	-	-	-	-
	14	15.00	15.00	5.00	10.00	10.00	5.00	-	5.00	-	5.00	5.00	-	-	-	-
	15	-	-	-	15.00	15.00	-	-	-	-	5.00	5.00	-	-	-	-
	16	5.00	5.00	-	10.00	5.00	-	-	-	-	5.00	5.00	-	-	-	-
	17	10.00	10.00	5.00	15.00	10.00	10.00	-	-	-	10.00	10.00	10.00	-	-	-
	18	15.00	10.00	5.00	5.00	5.00	5.00	-	-	-	-	-	-	-	-	-
	19	10.00	10.00	5.00	5.00	5.00	-	-	-	-	5.00	5.00	5.00	-	-	-
	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	21	5.00	5.00	-	-	-	-	-	-	-	10.00	10.00	-	-	-	-
	22	-	-	-	-	-	-	-	-	-	5.00	5.00	-	-	-	-
Group II	23	10.00	5.00	5.00	5.00	5.00	5.00	-	-	-	5.00	5.00	-	-	-	5.00
	24	15.00	10.00	-	5.00	5.00	-	-	-	-	5.00	5.00	-	-	-	-
	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	26	-	-	-	5.00	-	-	-	-	-	2.00	0.00		-	-	-
	27	15.00	15.00	5.00	-	-	10.00	-	-	-	5.00	5.00	-	-	-	5.00
	28	10.00	10.00	-	-	-	-	-	-	-	15.00	10.00	-	-	-	-
Group III	29	-	-	5.00	-	-	-	15.00	10.00	-	-	-	-	-	-	-
	30	10.00	10.00	-	15.00	10.00	10.00	15.00	10.00	10.00	-	-	-	-	-	-

Note. [Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up, - = No data / No Standard deviation]

18. Individual data for compensatory articulatory errors (nasalization errors) in individuals with VPD

Groups	Sub. No	Errors due to Nasalization (%)											
		NF			NOC			SNOC			WOPC		
		CI	C II	C III	C I	CII	C III	C I	C II	C III	C I	C II	C III
Group I	1	-	-	-	20.00	5.00	-	5.00	15.00	-	30.00	25.00	-
	2	10.00	10.00	-	10.00	-	5.00	-	10.00	-	40.00	40.00	20.00
	3	5.00	5.00	-	15.00	10.00	-	10.00	10.00	-	30.00	30.00	-
	4	10.00	10.00	5.00	-	5.00	5.00	-	10.00	-	20.00	20.00	10.00
	5	10.00	10.00	10.00	-	-	-	-	-	-	25.00	20.00	15.00
	6	10.00	10.00	5.00	-	10.00	-	10.00	-	10.00	30.00	25.00	20.00
	7	10.00	10.00	5.00	10.00	5.00	10.00	5.00	10.00	5.00	50.00	50.00	25.00
	8	-	-	-	15.00	-	-	-	10.00	-	30.00	20.00	-
	9	-	-	-	10.00	-	5.00	-	10.00	-	20.00	15.00	5.00
	10	10.00	10.00	-	-	10.00	-	10.00		-	35.00	35.00	-
	11	-	-	-	10.00	-	-	-	10.00	-	20.00	20.00	-
	12	10.00	10.00	-	-	10.00	-	10.00	-	-	40.00	40.00	-
	13	-	-	-	15.00	5.00	-	5.00	5.00	-	20.00	10.00	-
	14	15.00	15.00	-	-	5.00	5.00	5.00	-	-	35.00	35.00	15.00
	15	10.00	10.00	-	-	-	10.00	-	10.00	-	25.00	25.00	10.00
	16	5.00	5.00	-	10.00	-	-	-	5.00	-	20.00	20.00	-
	17	-	-	-	-	5.00	5.00	5.00	-	-	30.00	20.00	20.00
	18	20.00	10.00	15.00	10.00	5.00	10.00	-	10.00	-	40.00	30.00	25.00
Group II	19	5.00	5.00	5.00	-	5.00	-	5.00	5.00	5.00	25.00	25.00	15.00
	20	5.00	5.00	-	10.00	-	-	-	5.00	-	10.00	10.00	-
	21	-	-	-	5.00	10.00	-	10.00	5.00	-	25.00	20.00	-
	22	5.00	5.00	-	5.00	5.00	-	-	5.00	-	10.00	10.00	-
	23	5.00	5.00	-	-	10.00	-	10.00	-	5.00	30.00	20.00	15.00
	24	10.00	10.00	-	10.00	-	-	-	10.00	-	30.00	25.00	-
	25	15.00	15.00	-	5.00	-	5.00	-	5.00	5.00	20.00	20.00	5.00
	26	10.00	5.00	-	5.00	-	5.00	-	5.00	5.00	10.00	10.00	10.00
Group III	27	10.00	10.00	-	10.00	-	-	-	10.00	10.00	35.00	35.00	20.00
	28	15.00	15.00	-	-	-	-	-	-	-	25.00	25.00	-
	29	15.00	15.00	-	10.00	5.00	-	5.00	10.00	-	20.00	20.00	-
	30	5.00	-	-	15.00	-	5.00	-	15.00	-	20.00	20.00	20.00

Note. [Group I (GI) = Palatoplasty, Group II (GII) = Pharyngoplasty, Group III (GIII) = Combined Surgery, Condition I (CI) = Pre surgery, Condition II (CII) = 3 months follow up, Condition III (CIII) = 6 months follow up, NF= Nasal Fricatives, NOC = Nasalization of Oral Consonants, SNOC = Substitution of Nasal for Oral Consonants, WOPC = Weak Oral Pressure Consonants, - = No data / No Standard deviation]