EFFECT OF PALATAL PROSTHESIS ON FEW SPECTRAL PARAMETERS OF SPEECH IN CLEFT LIP AND PALATE: A CASE STUDY

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Abstract

Rehabilitation of speech disorders in the cleft lip and palate population requires teamwork of plastic surgery, palatal prosthesis, and behavioral therapy. The present study is an attempt to provide an insight on the effect of the palatal prosthetic management in cleft lip and palate. Systematic outcome studies of the effectiveness of palatal prosthetic appliances are required to document towards the evidence based practice. The study is aimed to investigate the acoustical parameters (Energy concentration, formant frequencies F1 and F2.) of speech with (during various stages of preparation) and without palatal prosthesis and to compare with the acoustic parameters of the control subject. This study also examines the velopharyngeal closure with and without using the palatal prosthesis. Materials used for acoustic analysis are repetition of three unaspirated stop consonants in the context of vowel /a/ was considered as the stimuli (/pa/, /ṭa/, and /ka/) and for physiological analysis image of the velopharyngeal closure of the phonation of /a/ was considered. The individual, aged 17 years male with huge palatal fistula was recommended for palatal prosthesis by the cleft palate team members. Age and gender matched control subject was considered as a control subject in the study. The experimental subject was fitted with the palatal obturator and extension and elevation of the prosthesis was provided in various stages to achieve the velopharyngeal closure. Pratt software was used to extract the spectral aspects of speech during the stages. Velopharyngeal closure was evaluated using nasoendoscopy. The acoustic parameters were extracted before and after fitting at various stages of fitting of prosthesis with different elevation or extension of the obturator and compared with normal subject. The result indicates difference in F1, F2 and energy concentration between the control subjects. The variation in formants was also observed with and without prosthesis.

Key words: *Prosthesis, Acoustic analysis, Perceptual analysis***.**

Speech is the key to human existence. Speech production is a process where the concepts, ideas and feelings are converted into linguistic code, linguistic code into neural code and neural code into muscular movements and finally muscular movement leads to acoustic signal (Ainsworth, 1975). Disturbance in any of these chain of events lead to disordered speech production.

Cleft is an abnormal opening or a fissure in an anatomical structure that is normally closed. A cleft lip and palate is the result of the failure of the parts of the lip and roof of the mouth to come together early in the life of the fetus. Clefts vary in length and width depending on the degree of fusion of the individual structures. The acoustical and perceptual parameters of speech characteristics also vary depending on the extent of the cleft.

The speech of experimental subjects with cleft palate is primarily characterized by abnormalities in nasal resonance. This is a direct result of unoperated cleft / fistula and or velopharyngeal dysfunction. The individuals with velopharyngeal dysfunction cannot either adequately or consistently close the velopharyngeal port during speech leading to nasal escape of sound energy. In addition, there may be articulatory errors, including compensatory articulations and reduced voice quality resulting in poor speech intelligibility (McWilliams, Morris & Shelton, 1990; Kuehn & Moller, 2000; Kummer, 2001; Peterson-Falzone, Hardin-Jones & Karnell, 2001; Bzoch, 2004).

Speech problems exhibited by experimental subjects with cleft palate can be studied by acoustical, perceptual and physiological methods. Acoustic analysis offers the opportunity to observe the speech patterns resulting from simultaneous and sequential interactions of phonation, resonation and articulation as these occur in real time speech production. Spectrographic data have been used frequently to study cleft palate speech (Horii, 1980).

The formant frequencies of a speech sound are directly dependent on the shape and size of the vocal tract. They are largely responsible for the characteristic quality of the speech sound. The formants enable to recognize different speech sounds which are associated with different

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positions of the vocal tract (Ladefoged, 1962). According to Stevens (1998), in the production of stops in initial pre-vocalic position, there is a change of the vocal tract configuration from that of the complete closure for stops to the shape of the following vowel. The release of the vocal tract obstruction results in changes in the cross-sectional area of the vocal tract constriction which is associated with a corresponding change in formant frequencies. The changes in formant frequencies depend on the place of oral constriction. Hence the formant frequency is an important parameter to study the cleft palate speech.

The vowels in normal speech are characterized by a well defined formant pattern in wide band spectrograms. But in experimental subjects with cleft palate or velopharyngeal dysfunction vowels are characterized by nasalization (Fant, 1970). The acoustic effects of nasalization vary across speakers and phonetic contexts. The acoustic correlates of vowel nasalization include appearance of the low frequency nasal formant below F1 of the non nasalized counterpart, a weakening and small frequency increase of F1, a reduction of the overall energy, a reduction of F2 amplitude and an increase in the formant bandwidth. The overall effect is nasalized vowels sound less intense, more weighted with low frequency energy and more uniform in the distribution of energy in the mid frequencies (Philips & Kent, 1984). F1 for the nasal vowel is less prominent than for the oral vowel and is surrounded by shallow valleys. F1 region for the nasal vowel is less intense and flatter. These effects reflect the greater damping for the nasal vowel and addition of nasal formants and antiformants. The nasal vowel typically has a low frequency resonance below F1 is called as nasal murmer.

The rehabilitation of individuals born with cleft lip and palate and related craniofacial anomalies require coordination of plastic surgery, prosthetic intervention and behavioral therapy. A multidisciplinary approach is essential to achieve optimum results. Definitive prosthodontic treatment is usually one of the final therapies instituted and it must attempt to alleviate any anatomical and functional deficiencies that may remain after the gamut of other treatment is essentially completed. Residual palatal deficiencies may remain after surgical treatment, which would necessitate placement of obturator prosthesis. Also, selected cleft palate patients with gross deficiencies of palatal tissues are best treated prosthodontically, without surgical intervention (Bhat, 2007).

With the advances in techniques for fabrication of speech appliances, this treatment may be a routine option in the rehabilitation of persons with velopharyngeal dysfunction / palatal insufficiency, which may provide socially acceptable speech and consequently improve the individual social relationships. Speech appliances are used to facilitate speech by separating the nasopharynx from the oropharynx and help to reduce nasal air emission and improve speech intelligibility. Several investigators have advocated the use of speech bulbs as an effective treatment either as an alternative to surgery or as a secondary procedure to improve velopharyngeal closure (Pinborough-Zimmerman, Canady, Yamashiro & Morales 1998; Reisberg, 2000; Tachimura, Nohara, Fujita, & Wada, 2002). Only few investigators have tried to analyze the influence of speech appliance on acoustics of speech (Shelton & Blank, 1984; Henningson & Isberg 1987).

Lindblom, Leuker and Pauli (1977) and Lubker (1979) have compared the nasal and non nasal sounds produced by a speaker with cleft palate with and without wearing a palatal appliance. The results indicated that the vowels produced with the obturator were more distinct than those produced without. McGrath and Anderson (1990) reported a review of the outcome management of two hundred persons with cleft palate and found that 95% were able to overcome both hyper-nasality and nasal emission distortions in speech through prosthetic management. Jian, Ningyi, and Guilan, (2002) investigated the effect of a temporary obturator to treat VPI and found that velopharyngeal closure can be greatly improved by using a temporary oral prosthesis and speech training.

Tachimura, Kotani, and Wada (2004) studied the effect of palatal lift prosthesis on children with repaired cleft palates exhibiting hypernasality or nasal emission of air without any compensatory articulation and found that with palatal lift prosthesis decrease the nasalance score for speakers with repaired cleft palate with affected velopharyngeal function. Pinto, Dalben, and Pegoraro-Krook, (2007) conducted a study on 27 experimental subjects with unoperated cleft palate/ or operated cleft palate with velopharyngeal insufficiency (VPI) after primary palatoplasty, treated with speech prosthesis suitable to their dental needs, and the speech was recorded with/ without porsthesis. The samples were blindly evaluated by 5 speech pathologists and results concluded that speech Intelligibility may be improved by using appropriate speech prosthesis.

Perceptual analysis was widely used to study the efficacy of the prosthesis (Subtelny, Sakuda & Subtelny, 1966; Pinto, Dalben, & Pegoraro-Krook, 2007). But, acoustical analysis is an important aspect to be studied in cleft lip and palate. In literature several studies (Curtis, 1968; Maeda, 1982; Watterson & Ehanuel, 1981; Schwartz, 1971; Ericsson, 1980; Seunghee, Hyunsub, Zhi, & Kuehn, 2004) have been done on acoustic analysis in children with cleft lip and palate.

There are few studies done in the Indian context to investigate the effect of obturator on speech characteristics. Pushpavathi and Sreedevi (2004) analyzed the speech of a experimental subject with submucous cleft palate who was recommended palatal lift prosthesis. The acoustical parameters were studied by obtaining formant frequencies F1 and F2 with and without prosthesis. The results indicated that F2 was higher with prosthesis compared to the without prosthesis condition. The nasoendoscopy also revealed a better velopharyngeal closure with the prosthesis. But there is dearth of studies for proving efficacy of prosthesis using acoustical and physiological parameters.

The present study is a part of the longitudinal study of a project aimed to evaluate the effect of prosthesis on acoustical and perceptual characteristics of speech. Hence, this is a preliminary attempt to study the effect of using prosthesis in terms of acoustical findings and physiological measurements. The purpose of this study is to present a case report of an individual with palatal insufficiency with wide fistula and was fitted with a palatal obturator. This study is aimed to evaluate the effect of palatal prosthesis on some spectral characteristics of speech by evaluating acoustic and physiological characteristics of speech across the stages of adaptation to the prosthesis.

Objectives of the study

To investigate the difference in:

a) First and second formant frequencies between experimental subject with cleft palate without prosthesis (S1) and with prosthesis (S5) and a control subject.
b) Energy concentration at F1 between a experimental subject with cleft palate without prosthesis (S1) and with prosthesis (S5) and a control subject
c) First and second formant frequencies with and without palatal prosthesis (across stages of adaptation to the prosthesis with different elevation / extension of the obturator to the velar portion of the palate).
d) Energy concentration at F1 with and without palatal prosthesis (across stages of adaptation to the prosthesis with different elevation/ extension of the obturator to the velar portion of the palate).
e) To examine the velopharyngeal closure with and without prosthesis through nasoendo-scopy

Method

Experimental subject

A 17 year-old male with congenital cleft lip and palate and moderate retardation served as experimental subject of the present study. He underwent plastic surgery for cleft lip at the age of 3 years. Since he had a wide palatal cleft, the surgery for the palate was not successful due to lack of tissue which lead to palatal fistula. On speech evaluation by speech language pathologist, he was diagnosed to have hypernasality and misarticulations. The cleft palate team constituting of plastic surgeon, orthodontist, prosthodontist, speech pathologist and psychologist recommended for the prosthetic management. The prosthodontist provided palatal obturator only to the anterior portion of the hardpalate to the experimental subject and gave two weeks time to get adjusted to it. Then, the prosthesis was extended to the velar portion of the palate and provided one month time to get adapted. During this one month, based on the feedback from the experimental subject and perceptual analysis of speech, prosthodontist made modifications to the velar section of the prosthesis till adequate velopharyngeal closure was achieved.

Recordings of the speech samples were done before and across the various stages of adaptation to the prosthesis. The experimental subject was evaluated during the adaptation stages of the prosthodontic management in terms of acoustical and physiological measurements as described in the procedure below. An age and gender matched control subject was chosen and speech recording was done to extract the data for the acoustic analysis.

Figure 1: *Wide palatal fistula*

Figure 2: *Final Prosthesis*

Figure 3: *Palatal prosthesis in Situ*

Procedure

Speech sample was obtained from the experimental subject at various stages during adaptation to the prosthesis as follows:

- Stage 1(S1): Before initiating the prosthetic management (Pre-treatment recording)
- Stage 2(S2): After providing anterior part of the palatal prosthesis.
- Stage 3(S3): After providing extension to the obturator to the velar portion of the palate and using the same for two weeks.
- Stage 4(S4): After one month of usage of the palatal obturator with velar extension
- Stage 5(S5): After doing the necessary modifications based on the experimental subject's feedback and using the obturator with velar extension for one month.

All the speech samples were recorded after the experimental subject got adjusted to the prosthesis.

Stimulus and Recordings for Acoustic Analysis

The study aimed to extract the first and second formant frequencies and their energy concentrations. Three unaspirated stop consonants in the initial position and in the context of vowel /a/ were considered as the stimuli (/pa/, /ṭa/ & /ka/). The experimental subject was seated comfortably in a sound treated room and was asked to repeat /pa/, /ṭa/ & /ka/ five times at his comfortable level. The stimuli were recorded using the *PRAAT 5.1* software, sampling size is 44,000, and the formant frequencies (F1 and F2) of the vowel and energy concentration at first formant (E1) were extracted and analyzed. The same procedure was used for age and gender matched control subject.

Analysis

The following analysis was done before and across the stages of adaptation to the prosthesis

Step I: Acoustical Analysis

Speech samples were carried out for acoustical analysis to obtain the formant frequencies F1 and F2 of vowel /a/ and energy concentration at F1. The lowest band of continuous stretch of darkness at the lowest end of the spectrogram was denoted as F1. The next higher band with a noticeable stretch of darkness was denoted as F2.

Step II: Physiological evaluation

To study the physiological aspects of velopharyngeal closure using *NASOENDOSCOPY - CS 400*, this provides the visual display of the velopharyngeal closure. The experimental subject was asked to phonate vowel /a/ and the images of velopharyngeal closure were captured without prosthesis (S1) and with prosthesis (S5). Later the recorded images were correlated with acoustical findings.

Results and Discussion

The study aimed to analyze the effect of palatal obturator on some spectral and physiological aspects of the speech of an experimental subject with huge palatal cleft with VPD and comparing the same with the control subject.

A) Comparison of F1 and F2 between experimental subject and control subject in S1 and S5 conditions.

The formant frequencies F1 and F2 were measured for vowel /a/ across the three phonetic contexts /p/, /ṭ/ & /k/. The comparison was made between S1 and S5 conditions of experimental subject with the control subject in the formant frequencies F1 and F2. The results are depicted in Table 1 and Figure 4.

Table 1: *F1 & F2 of experimental subject and control subject in S1 and S5 conditions.*

Subject	F1 (Hz)			F2 (Hz)		
	/pa/	/ṭa/	/ka/	/pa/	/ṭa/	/ka/
Control subject	627	614	589	1236	1360	1348
Experimental subject in S1 condition	812	745	854	1274	1711	1529
Experimental subject in S5 condition	836	870	880	1183	1532	1450

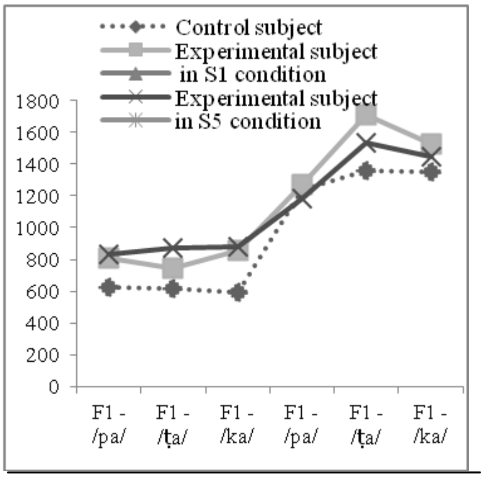

Figure 4: *F1 & F2 of experimental subject and control subject in S1 and S5 conditions.*

In general, the results revealed that the experimental subject exhibited high F1 and F2 in both S1 and S5 conditions compared to the control subject. However, high F1 is observed in S5 than in S1, and low F2 is observed in S5 than in S1. The variations in the F1 and F2 depend on the oral tract configuration based on the placement of the tongue. These variations in the F1 and F2 across the stimuli can be attributed to the contextual effect. The tongue placement for /ṭ/ and / k/ is more towards the mid and the posterior part of the palate. The experimental subject might have narrowed and retracted the tongue towards back of the oral cavity during the production of the target syllables, leading to high F1 in both S1and S5 conditions. This is possible because he had a cleft of the palate he might have developed compensatory articulation (pharyngeal plosive) by moving the base of the tongue back to articulate against the posterior pharyngeal wall. This result supports the findings by Fant (1973) who stated that retraction of the tongue increases the first formant comparatively to the other formant frequencies. Stevens and House (1955) also reported a high F1 with the articulatory event characterized by a narrow tongue constriction by a few centimeters above the glottis and an unrounded large mouth opening. Hence, the variation in the formant frequencies can be attributed to the variations in the articulation by the experimental subject. These results are also supported by the findings of Vasanthi (2001) who reported higher F1 and lower F2 in cleft palate speaker compared to the normal speaker. Even after using prosthesis (S5 condition) high F1 is noted, resulting from compensatory articulation. To eliminate compensatory articulation regular speech therapy is necessary along with prosthetic management (Arndt, Shelton, & Bradford, 1963; Pinto, Dalben, & Pegoraro-Krook, 2007).

B) Comparison of energy concentration (E1) at F1 between experimental subject in S1 and S5 conditions and control subject.

The energy concentration (E1) was measured at F1 for /a/ vowel across the three phonetic contexts /p/, /ṭ/ & /k/. The measurements were done between the control subject, and experimental subject in S1 and S5 conditions. The results are shown in the following Table 2 and Figure 5.

Table 2: *Energy concentration (E1) of, experimental subject in S1 and S5 conditions and control subject.*

Subject	Energy concentration (E1) in dB		
	/pa/	/ṭa/	/ka/
Control subject	56	55	57
Experimental subject in S1 Condition	71	70	69
Experimental subject in S5 Condition	70	66	67

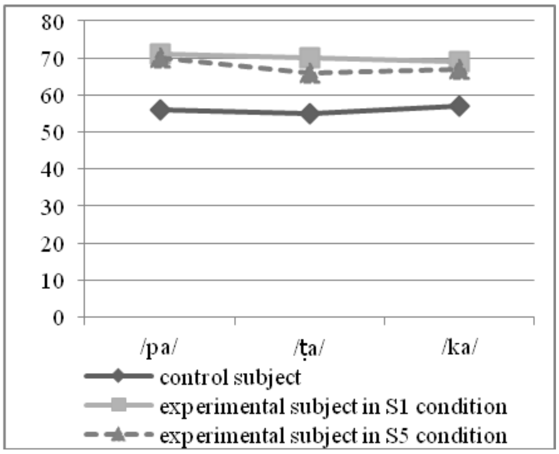

Figure 5: *Energy concentration (E1) of experimental subject in S1 and S5 conditions and control subject.*

The results indicate that E1 was high in experimental subject both in S1 and S5 compared to the control subject. Though the energy concentration in experimental subject was relatively reduced from S1 to S5, it was still higher than the control subject. This may be because, the experimental subject used loud pattern of habitual voice to achieve intelligible speech. Most of the subjects with cleft lip and palate attempt to speak with wide opening of the mouth to improve the oral resonance quality which inturn increases the loudness. The results support the findings of Zraick and Case (1999) who found the correlation of nasality, pitch and loudness reported that perception of increased nasality was related to increased loudness and an increase or decrease in pitch.

C) Comparison of F1 and F2 without prosthesis (S1) and the across the stages (S2 to S5) of adaptation by the experimental subject.

The F1 and F2 for vowel /a/ were measured across the stimuli /pa/, /ṭa/ & /ka/.The measurements were done without prosthesis (S1) and across the stages of adaptation (S2 to S5) to the prosthesis to find the differences in the first formant frequencies. The results are given in the following Table 3 and Figure 6.

In general, the results indicated that the F1 for all the stimuli increased from S1 to S3, however, decreased from S3 to S5. Overall there is a slight increase in the F1 with prosthesis (fifth recording). The first formant depends on the height of the tongue and the constriction of the pharynx (Jacobson & Halle, 1956). The variations in the formant frequency can be attributed to the alterations in the constriction of the oral cavity and the tongue placement in the process of adaptation at various stages of the prosthesis. However the drastic increase in the F_1 between the first and the second recordings may be due the presence of anterior part of the obturator occupying anterior part of the fistula. This might have altered the movement of the tongue due to the presence of the prosthesis. The experimental subject might have altered the rate and movement of tongue which might have influenced the F1.

Table 3: *F1and F2 for vowel /a/ across stimuli and across stages of adaptation to the prosthesis*

Stimuli	F1 (Hz) in Conditions					F2 (Hz) in Conditions				
	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5
/pa/	812	1085	1049	927	836	1274	1282	1241	1329	1183
/ṭa/	745	982	1103	870	870	1711	1657	1765	1550	1532
/ka/	854	995	1175	942	880	1529	1570	1586	1443	1450

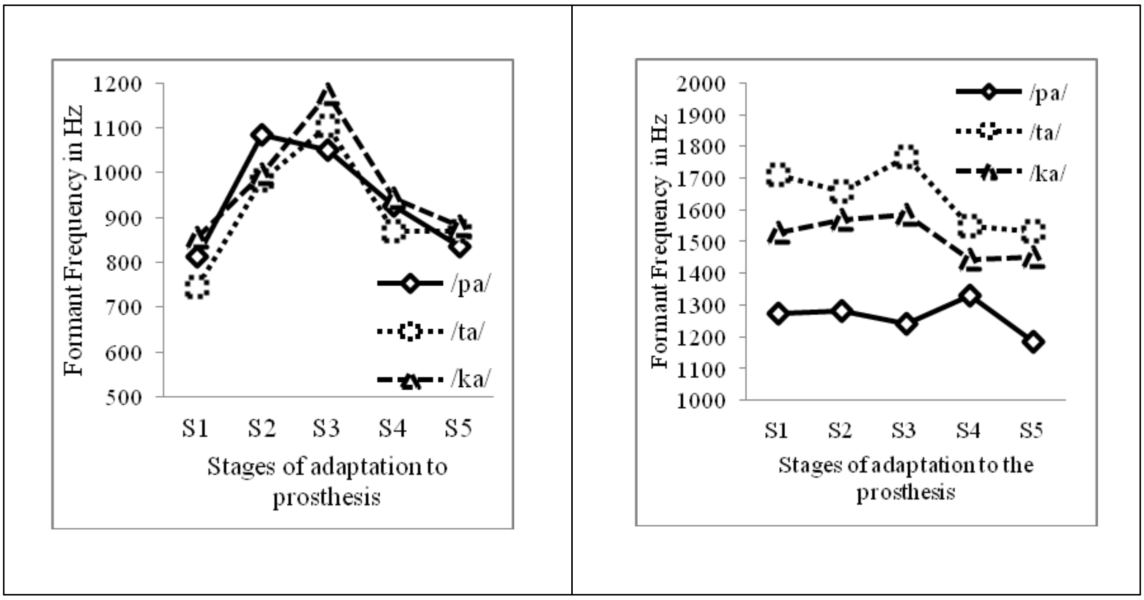

Figure 6: *F1 and F2 for vowel /a/ across stimuli and across stages of adaptation to the prosthesis*

These results are in contradiction to the findings of Pushpavathi and Sreedevi (2004) who reported a reduction in the first formant frequency with prosthesis in a submucous cleft palate individual. The difference in the result may be attributed to the nature of the cleft. According to Casal et.al, (2002) there are significant differences in the spectral characteristics exhibited by the experimental subject with various types of cleft lip and palate.

The results support the findings of Philips and Kent (1984) reported that the acoustic effects of nasalization vary across speakers and phonetic contexts.

The results indicate slight variations in F2 across the stages of adaptation to the prosthesis. Overall there is a decrease in the F2 with prosthesis (fifth recording) than without prosthesis (first recording). The variations in F2 can be observed across the phonetic contexts, where the lowest F2 was denoted in the context of /pa/ followed by /ka/ and /ta/. This may be due to the backing of the tongue towards the velar section of the prosthesis during the production of the stimuli. With the presence of the extended velar portion of the prosthesis, experimental subject might have attempted to articulate the vowel at the posterior portion of the oral cavity. The F2 depends on the tongue advancement in the oral cavity. This supports the findings of Fant (1973) who correlated the medium or low F2 with the velar and the pharyngeal articulation. However, the results are in disagreement with the findings of Pushpavathi and Sreedevi (2004) who reported an increase in the second formant frequency using prosthesis in a submucous cleft palate experimental subject. This can be attributed to the nature of the cleft and compensatory mechanism adopted by the experimental subject.

D) Comparison of E1 between without prosthesis (S1) and the across the stages of adaptation (S2 to S5) to the prosthesis by the experimental subject.

The energy concentration was measured E1 for vowel /a/ across the three phonetic contexts. The measurements were done without prosthesis S1 and across the stages (S2 to S5) of adaptation to the prosthesis to find the differences in the energy concentration. The results are shown in the following Table 5 and Figure 7.

Table 5: *E1 for vowel /a/ across stimuli and across stages of adaptation to the prosthesis*

Stimuli	E1 (dB) in Conditions				
	S1	S2	S3	S4	S5
/pa/	71	71	69	72	70
/ta/	70	69	67	70	66
/ka/	69	70	68	70	67

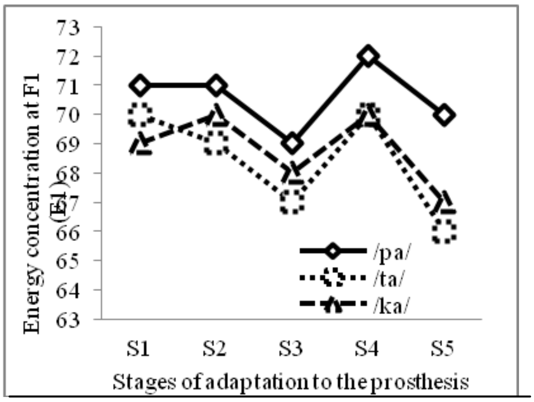

Fig 7: *E1 for vowel /a/ across stimuli and across stages of adaptation to the prosthesis.*

In general the results indicated that the energy concentration decreases from S2 to S5. This indicates that, the experimental subject loudness decreases as he got adopted to use the prosthesis. This result supports the findings by Pushpavathi and Sreedevi (2004) who reported the reduced energy concentration with the prosthesis than without prosthesis in a submucous cleft palate.

Physiological Measures

The physiological assessment was done through the nasoendoscopy. The nasoendoscopy was used to measure the velopharyngeal closure during the first stage (S1) and the fifth stage (S5). The images were taken when the experimental subject phonated /a/ in both the conditions. The findings of the physiological measures revealed a good velopharyngeal closure with the prosthesis. The image S1 (Fig 8) showed gap of the velopharyngeal closure and S5 showed a good closure condition. The closure S5 (Fig 9) condition might have lead to the better results in speech which was reflected in the results obtained for formants F1, F2 and energy concentration at F1. This result support the findings of Jian, Ningyi, and Guilan, (2002) who reported improvement in velopharyngeal closure by using a temporary oral prosthesis and speech training.

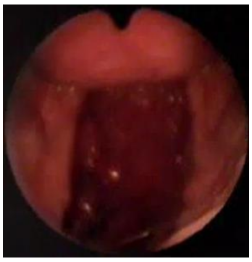

Figure 8: *Open velopharyngeal port in S1condition*

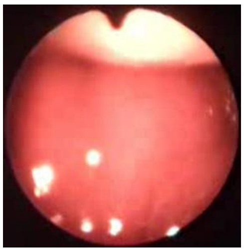

Figure 9: *Closed velopharyngeal port in S5 condition*

Conclusions

The present study investigated the effect of palatal prosthesis on few spectral characteristics of speech. A 17 year old boy with palatal fistula was considered as a experimental subject. He was recommended palatal prosthesis. In order to investigate the effect of palatal prosthesis, the formants frequencies F1, F2 and energy concentration (E1) was measured across phonetic contexts in control subject and experimental subject with prosthesis across the different adaptation stages. Overall, the results indicate that, the formants and energy concentration was different in control subject compared to experimental subject across conditions. The difference in acoustic values across conditions S1 to S5 suggested that the experimental subject is achieving better speech compared to S1 condition. The analyses of the same parameters are required after the experimental subject is completely rehabilitated to use the prosthesis and attends speech therapy. The findings are preliminary in nature to conclude on the efficacy of the prosthesis. But, the study may add to the existing literature on the efficacy of palatal prosthesis in the rehabilitation.

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