ACOUSTIC AND PERCEPTUAL ANALYSIS OF THE T.E.P. SPEECH WITH DIFFERENT TYPES OF PROSTHESIS

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A dissertation submitted as part fulfilment for the final year M.Sc. (Speech and Hearing) to the University of Mysore

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MAY 1993

To

My

Parents,

Brothers & Sisters.

CERTIFICATE

This is to certify that the dissertation entitled **"ACOUSTIC AND PERCEPTUAL ANALYSIS OF THE T.E.P. SPEECH WITH DIFFERENT TYPES OF PROSTHESIS"** is a bonafide work, done in part fulfilment for the Degree of Master of Science (Speech and Hearing), of the student with Reg.No.M9119

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This is to certify that the dissertation entitled " **ACOUSTIC AND PERCEPTUAL ANALYSIS OF THE T.E.P. SPEECH WITH DIFFERENT TYPES OF PROSTHESIS**" has been prepared under my supervision and guidance.

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Dr. N.P. NATARAJA
Guide

DECLARATION

I hereby declare that this dissertation entitled **"ACOUSTIC AND PERCEPTUAL ANALYSIS OF THE T.E.P SPEECH WITH DIFFERENT TYPES OF PROSTHESIS** "is the result of my own study under the guidance of **Dr. N.P.NATARAJA,** Professor and HOD, Speech Science, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any University for any other Diploma or Degree.

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CHAPTER - I

INTRODUCTION

Speech is the greatest achievement of mankind during the process of evolution. All the joy of life vanish the moment speech is taken away and existence without the real power to communicate can not be endured.

Even Daniel Webster says ''if all my possessions were taken from me with one exception I would choose to keep the power of speech, for by it I would soon regain all the rest.''

Cancer of the larynx calls for surgical or radiological intervention. These can be partial or total removal of the larynx and this may lead to significant alteration or complete loss of speech.

Hence speech rehabilitation of the laryngectomised patients is vital and interesting as it amounts to a new life for them. So, voice restoration following total laryngetomy remains a challenging problem for both Head and Neck surgeon and speech pathologist.

Rehabilitation efforts to re-estabilish speech in laryngectomees have centered around two methods i.e. 1. The time honoured oesophageal speech method, 2. The electrical or artificial larynx (Which is not preferred for it's mechanical and inferier vocal quality.)

Since 1973, when Billroth performed the first total largectomy in Vienna, speech rehabilitation in the total laryngectomy patient has been a major goal of the surgeon. In US alone there are an estimated 11,000 new cases of largngeal cancer diagnosed each year, with approximately 2,500 to 3,000 total laryngectomies being performed. Only one-half of these patient will ever be able to develop adequate oesophageal voice. Thus, the need for an alternative to oesophageal voice became rapidly apparent.

Since the original larygectomy, many different techniques have been utilized to restore speech. Conley et. al. (1958) introduced an internal tracheoesophageal tunnel, Asai procedure in 1959, voice Bank prosthesis by Taub and Spiro in 1972, phonatory neoglottis by Staffieri in 1976. But none of the above mentioned surgical procedures have been accepted form of rehabilitation because most of them suffered from the problem of aspiration.

Blom and Singer (1979) introduced a technique of Tracheo-oesophagical puncture with placement of a one-way silastic valve. They gave the fundamental impetus for the development of these new prosthesis. Aspiration with this prosthesis is minimal. After this a range of prosthesis were developed like Blom-Singer's low pressure prosthesis, Panje voice button. Groningen's prosthesis, H-C prosthesis.Provox prosthesis, Indian prosthesis etc. These prostheses were developed in different part of the world for the following reasons.

1. By knowing and correcting the drawbacks of existing prosthesis may begets renewed prosthesis.

2. To make it available indigenously rather than importing from other places.

3. To reduce the expenses.

There have been studies on acoustic parameters of oesophageal and TEP sppech characteristics.Most of these studies concludes that the TEP speech is better as compared to oesophageal speech.

Acoustic analysis of voice has practical advantages in clicnical application since it is non invasive, doesn't require close co-operation from the patient and can be made off-line from tape recorders (Lofgvist and Mandersson, 1987) . The knowledge of acoustic properties of TE speech represents an important body of infarmation and a significant area of theoretical and applied study and can be interpreted in such a manner as enlarge understanding of speech production following TEP. There have been studies which compare different types of prosthesis. They concentrate only on frequency and intensisty Parameters, This study was undertaken to compare 3 types of prosthesis (Blom - Singe's duck-bill and low pressure prosthesis and Indian prosthesis) on frequency, intencity, temporal and spectral parameters. Acceptability and intelligibility of speech are also studied to know which one is more accepted. Hence the present study was planned with the following objectices.

AIM OF THE STUDY

1. Acoustic analysis of the T.E.speech when the same laryngetomee used differente types of prosthesis.

2. To determine the acceptability and intelligibility of T.E. speech with different types of prosthesis.

Hypotheses :

There is no significant difference in terms of the parameters studied between

(a). T.E.Speech and normals,

(b) Duck-bill prosthesis aided and B.S. Low pressure prosthesis aided T.E.speech,

(c) B.S. duck -bill prosthesis aided and Indian prosthesis aided T.E. speech,

(d) B.S.low pressure prosthesis aided and Indian prosthesis aides T.E. speech.

Implications of the Study

1. The result of study would throw some light on TE speech with different prosthesis.
2. It would help in improving therapy techniques.
3. It would help in improving the prosthesis.

Limitations :-

1. Only 5 subjects have been studied
2. Only male speakers have been studies.
3. The study was limited to only some of the acoustic, temporal and spectral parameters.

CHAPTER - II

REVIEW OF LITERATURE

It took man about five years to build the atom bomb after he started seriously. It took man about ten years to hurl a couple of tons of metal into space after he decided he could do it. It has taken man & nature several million years to develop the human speech and voice to the current point of personal communication.

Robert M. DeuPress, (1971)

It is a well known fact that all living beings communicate with another. Only human being has the most complex of all communicating systems.

Speech is one of the initial tools of communication and the underlying basis of speech is voice. Voice has been defined in various ways. The one commonly accepted definition is given by Michel and Wendahl (1971). They define voice as laryngeal modulation of the pulmonary air stream, which is then further modified by the configuration of the vocal tract. Voice is not only used for speech but also it is used in singing and theatrical performances.

The production of voice is a complex process. It requires synchrony between the respiratory, the phonatory and the resonatory systems. Any anatomical, physiological or functional deviation in any of these systems would lead to a voice disorder. It is well estabilished that voice has both linguistic and non-linguistic functions in any language. The degree of dependence of language on these functions varies from language to language. " Tone languages '' for example rely more on the voice or pitch, more specifically than other languages.

Variations in voice in terms of pitch and loudness, provide rhythm and breaks the monotony. This function establishes the voice as the carrier of speech and draws attention in voice disorders. * voicing ' (presence of voice) has been found to be one of the major distinctive feature in almost all languages. The absence of this function results in speech disorder.

The voice also plays an important role at the semantic level. Use of different pitche variation with the same string of phonemes would alter the meaning. Speech prosody intonation, stress, rhythm of language is a function of.pitch and loudness as well as of phonetic duration.

Voice also has many non lingustic functions like speaker identity, emotion, personality, somatic condition, aesthetic function (Perkins, 1971). Voice provides information regarding sex, age, height and weight of the speakers Lass, Brong, Ciccolella, Walters and Maxell (1980) have reported several studies where in based on voice, it was possible to identify the speaker's age, sex, socio - economic status, racial features, height and weight. It is a well known fact that voice basically reflects the anatomical and physiological conditions of the respiratory, phonatory and resonatory systems. Voice is important for professional speakers and signers. Thus, voice has an important role in communication through speech. The importance of voice in speech is dramaticlly demands trated in a laryngectomee. Loss of voice has been found to lead to psychological, social and economic problems. These get aggrevated if the individual is depending on his voice for his living like in case of teachers, lawyers, politicians etc. Therefore restoration or providing alternate modes of voice production becames important.

Historical Review of Larynegeal Prosthetic Devices

Attempts have been made from the beginning of the 19th Century to provide alternate modes of voice generation to laryngectomes.

There are circumstances in which people must produce speech using a radically altered mechanical system. Patients who have undergone total laryngectomy are in such a situation. Alternate modes of voice production in laryngectomees can be generally classified as oesophageal, artificial laryngeal and prosthetically aided tracheoesophageal. Surgical removal of the larynx is a procedure often performed on patients with laryngeal cancer. India figures among the countries of the world with high incidence of laryngeal cancer. Laryngeal cancer is not an uncommon malignancy. Robin and Olofsson (1987) reported that theye is variation in its incidence across the globe, with India being among the countries with a relatively high incidence of more than 10 per 1,00,000 population. Variation in incidence occurs with in countries too. According to the Annual Report of National Cancer Registry (1983) published by ICMR (Feb. 1986) the incidence of laryngeal cancer in males per 1,00,000 population in Bombay based cancer registry was 15.2-6.94% of all cancers. It was low in South Indian centres, i.e. 5.5-4.9% in Madras; 9.7-3.81% in Bangalore. The incidence though expected to be higher, is less probably due to under reporting. Statistics from four Indian cancer Registeries show that the peak incidence is in the fifth and seventh decades of life (Annual Report of the National Registry, 1983, ICMR)

Voice restoration in laryngectomees has been a challenging problem for both Head and Neck Surgeon and Speech pathologists. Total laryngecto my necessitates removed of the entire larynx. All structures between and often including the hyoid bone and the upper tracheal rings are resected. The trachea is rotated forward and sutured to the base of the neck to creat a permanent respiratory stoma on the neck wall. Thus the total laryngectomy always results in a sacrifice of tissue essential for normal vocal function and in considerable alteration of the anatomy and physiology of the speech mechanism. As a result, the normal processes of speech are modified to such an extent that there is always a complete loss of the ability to produce voice by conventional means.

Laryngectomized patients compensate for this loss by using alternate methods of voicing for speech production. Compensatory approaches to speech restoration following total laryngectomy are 1. learning to produce oesophageal speech; 2. developing speech that is mediated, in part, on a surgical prosthetic basis and 3. to producing speech powered by some type of artificial larynx.

The production of alaryngeai speech necessitates the use oi non conventional air stream, phonatory and articulatory mechanisms. This notion has implications for diagnosis and management. One of the most important implications is that the speech reacquisition and training involves for more than getting the voice back '' (Weinberg, 1981)

The laryngectomee can generate sound at 3 locations : 1. In the oral cavity called `` buccal speech '' producing friction noises by trapping air between the tongue and cheek, 2. in the pharyngeal cavity termed as pharyngeal speech 3. at the lumen of the oesophagus known as ``esophangeal speech''. Of the various methods of sound production available oesophageal speech is the time honoured one.

Aronson (1980) stated that the oesophageal speech is based on the principle that when air is taken into the oesophagus sound is produced on the release of the air by exciting the upper oesophageal tract into vibration like ` belching ' Gottstein (1900) stated that Gluck was the first to introduce oesophageal speech as a speech restoration method for larngectomees in 1882.

Not all laryngectomees are able to acquire oesophageal speech . Reported percentages ranges from 43% (King, fowlks and Pierson, 1968) to 98% (Hunt, 1964).

An artificial larynx is a device meant to simulate an approximation to normal laryngeal tones. They have been developed mainly for individuals who have has their larynx surgically removed. The quality of Sound, the ease of use and other physical attributes vary greatly from device to device. It is difficult to say whether one device is better than the other since the individuals ability to use a device, the extent of surgery, and the amount of training as well as many other variables will make the output of the same device different for each patient (Goldstein L.P. 1982). Goldstein (1982) categorizes these devices into electronic and pneumatic, based on source of energy. The pneumatic prostheses are of two types i.e. external or internal. The electronic prostheses are classified as internal, transcervical implantable.

In 1972, Taub and spiro reported a combination of surgical-prosthetic approach to voice restoration. A fistula formed surgically between the oesophagus and skin surface was linked to the tracheostoma by air-pass device called the Voice Bak prosthesis voice was produced by a vibrating oesophagus powered by the pulmonary air.

Shedd (1972) developed a reed-fistula method of voice restoration, this method required a surgically created fistula leading to the pharynx. An external air by -pass and a pseudolarynx mechanism was inserted between the tracheostoma and the fistula.

Recent interest in the internal tracheal shunt was stimulated by the reports of Calcaterra and Jafek (1971). The method of internal shunting held promise because of avoidance of awkward devices and the mid line placement decreasing the likelihood of vascular injury. Air entering the oesophagus produced satisfactory voice and eliminated the need for reeds or other sound generating mechanisms.

A period of ten years from 1969 to 1978 saw the shifting back of surgeon's interest to the internal shunts. According to Singer (1983) a vocal rehabilitative method in laryngectomees should meet the follwoing critical criterion.

1. No limitation on adequate cancer treatment, either surgical or rediation.
2. Normal and rapid postoperative deglutition.
3. Avoidance of prolonged hospitalizati, convalescence, or excessive cost.
4. No dependance on complicated values, cannulas, or external devices.

Keeping these issues in mind, singer and Blom (1980) developed an endoscopic technique for voice restoration -Tracheo Esophageal puncture (T.E.P.) a surgical prosthetic approach. A high success rate in the acquisition of fluent speech by this method has been reported Mitzell, Andrews and Bowman (1985); Wetmore, Krueger, Wesson and Blessing (1985); Blom, Singer and Hamaker (1986); Pery (1988);Hazarika, Murthy, Rajashekhar and Kumar (1990); Rajashekhar, Nataraja, Rajan, Hazarika, Murthy and Venkatesh (1990).

TRACHEO - OESOPHAGEAL SPEECH

Over the last hundred years, many have attempted voice rehabilitation with a connecting canal between the respirator, tract and the digestive tract. In the last few years, voice prostheses have been developed to avoid aspiration via the connecting canal between the respiratory tract and the digestive tract. These prostheses allow air to flow into the pharynx and prevent leakage into the trachea. Blom and Singer (1980) gave the fundamental impetus for the development of one such new prosthesis known as Blom and Singer Prosthesis (B.S. Prosthesis).

The Singcr-Blom Tracheoesophagcal Puncture (T.E.P.) technique

The Singer -Blom technique for voice restoration provides pulmonary air for speech by diverting exhaled air from the trachea into the oesophagus (Singer and Blom, 1980). According to Blom and Singer (1980) the laryngeai speech mechanism used is conceptually simple. Through the trachaoesophageal tunnel, air flow of 100 - 150 cc /sec at pressures of 30 - 40 cm water is diverted when stoma is covered by finger to produce vibrations in the wails of the ncoph.irynx, producing sound. Sound is emitted from the orai cavity after passing through the articulators of the remaining vocal tract (singer, 1983). According to Jacksons (cited by Singer, 1983),`` the requirements (for pseude voice) are closely approximated membranous surfaces'' and a moving column of air that can be set into vibration by the membranous surfaces. This technique utilizes a one-way valved silicone prosthesis designed by Singer, an otoloaryngclogist, and Blom, a speech pathologist at the Indian University medical center & the veterans Administration Hospital in Indianapolis Indiana (Singer and Blom 1979). The term Tracheoesophageal puncture (T.E.P.) has been commonly used reference to the singer Blom Technique

(Evans/Drummond 1985).

The T.E.P. procedure as described by Singer & Blom 1980) is an endoscopic procedure, where a mid-line puncture is made from the trachea into the oesophagus. Post operatively, the surgeon and speech pathologist select the proper length prosthesis and insert it in the puncture site immediately after removal of the stenting catheter. Voice therapy is initiated with immediate voice obtained by occluding the stama. The patient is instructed in the care of the stoma and the prosthesis. The speech pathologist demonstrates the significance of controlled respiration, precise articulation, muscle relaxation and daily care involved in using the prosthesis.

General description of the prosthesis

Nowdays, different types of prosthesis are used by the TEP speakers. All of these prosthesis have some common structural part as follows :

A hollow tube (shaft) comes in different length and diameter to allow an exact fit with each type of fistula. Generally there will be two flanges in a prosthesis to hold the device firmly into the fistula, i.e, it prevents both prosthesis dislocation and leakage around the tube. Flange on the tracheal side is also called as retention collar which keeps device in close contact with the tracheal mucosa. Oesophageal side flange helps in holding the device firmly and preventing its falling into the trachea.

A slit or valve is present in the flange which acts as a one way valve. It remains closed during swallowing and opens only under low positive endotracheal pressure to diverte air into the hypopharynx for speech production.(see fig. 1)

Blom - Singer (B.S.) Voice Prostheses

Singer nd Blom (1980) introduced a method of TEP and silicone ``duckbill '' voice prosthesis for voice restoration following total laryngectomy. Details of this prosthesis and other prosthesis has been given in Appendix—II) Weinberg and Moon (1984) and Moon, Sullivan (1983) reported that total airway resistance offered by duckbill prosthesis ranged from 106.5 to 117.5 cm of water per litre per second (LPS).

A silicone device (voice button) was developed by Panje (1981) to prevent aspiration and stenosis and allowing vocalization. The device is 1.5 cm long. An inserter must be used which is made of wire and comes in various handle lengths to accommodate patient dexterity in order to place the voice button. Advantages of voice button over B-S prosthesis are : placement is accomplished with an outpatient surgical procedure reguiring no special instrument, the prosthesis is self contained with in the tracheostoma, it can't be dislodged unintentionally and no sizing is nedded. But the limitation is that the size of the tracheostoma must be atleast 1.5cm in diameter. Voice buttons are of two types

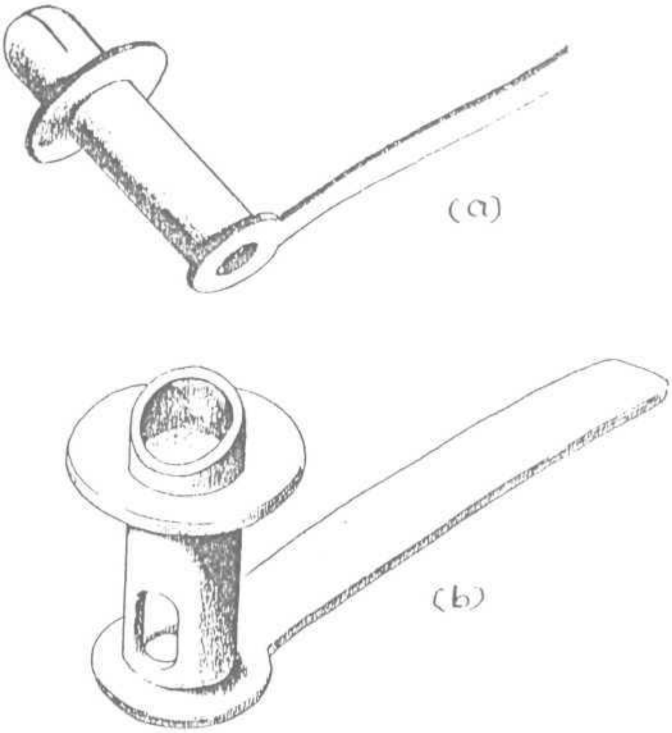


FIGURE-1: Blom-Singer's Prosthesis
(a) Duck-bill prosthesis
(b) Low-pressure prosthesis.

a). Short type which emanates 6mm from the inner flange, has a 4-flutter flap, one-way valve, used most frequently,

b). Long type - for patients who can't generate sufficient lung pressure for good long term vocalization and for same patient easier to insert than short type.

In 1982 , Blom, Singer and Hamaker introduced a proto type low-pressure voice prosthesis specially designed to reduce the airway resistance inherent in the duck-bill prosthesis. A series of studies (Weinberg and Moon 1982, Smith 1986) have demonstrated that low pressure type prosthesis have a lower total resistance to air flow than the original duckbill voice prosthesis when tested in vitro .

Nijdam Escajadillo (1984) developed a new prosthesis for vocal rehabilitation after laryngectomy called Groningen prosthesis. The prostthesis is placed in the T.E. wall as a primary procedure during laryngectomy or as a secondary procedure sometime after surgery. The prosthesis is self retaining and self cleaning. It's replacement is by a simple outpatient procedure. Manni JJ, Brock P, Groot and Berends E (1984) Success rate of 73% was obtained. As a primary procedure successful speech was acquired in 80% Vs 50% as a secondary procedure.

Henly - Cohn recently described a new prosthetic valve for use in the vocal rehabilitation of laryngectomized patients. The major advantages of the H-C prosthesis are :

1. One size of the device fits all patients provided the fistula is properly located.

2. Once insterted, the device can be retained in patients for 2 to 3 months without cleaning. The feature of the device is attributed to both the material used to make the device (HRT doped silicone which resists crusting and deterioration) and to the design of the device (self cleaning tip and medially placed retention flanges which diminish the extrusive forces associated with neck rotation and flesxion).

3. The device is said to offer less resistance to air flow than either B-S or panje voice button prostheses. The average total resistance of the H-C prosthesis was 68.5 Cm H_2O/LPS, 126 cm H_2O/LPS for the B-S and prosthesis and 194 cm H_2O /LPS for the panje voice button. The lower resistance of H-C prosthesis was shown to be due to both its large inner cross sectional area and to an improved valve tip design. This should result in more "efficient" production of oesophageal voice than the B-S prothesis or panje devices.

T.E. laryngeal device comparison.

Characteristics	Bivona B-S	Xomed panje	Dow corning H-C
1. opening pressure	Low	High	Very low
2. Air flow	medium	Low	High
3. Extrusion rate	High	Low	Low
4. Stoma obstruction	Yes	No	No
5. Valve crusting	High	High	Low
6. Self care difficulty	Moderate	Moderate	Minimal
7. Post-op visits	Many	Many	Few
8. Patient training	Moderate	Moderate	Minimal
9. Speech Fluency	Good	Fair	Very good
10. Speech Volume	Good	Fair	Very good

11. Speech Strain	Some	Moderate	Minimal
12. Device removal	Daily	Daily	2-3 mths.

Table - 1 Showing comparison of B.S., Panje, and H.C. prosthesis on different characteristics.

All these prosthesis show several disadvantages like difficulty in routine maintenance and irritability, problems in fitting into the fistula (especially just after the surgery). Some types are easily ejected from the fistula because the endoesophageal flange is too small and, thus, unable to hold the device securely in the fistula. Other with too narrow an endoesophageal retention collar, don't prevent aspiration or leakage along the fistula wall, still others greatly impede speech. It was with this in mind that a new silicone T.E. voice button was developed by Mario staffieri & Alberto Staffieri (1986) This new voice button displays very good aspiration control and very low impedance with no maintenance problem.

Presently many prosthesis for voice rehabilitation, such as the BS prostheses, the panje button and the Groningen button are available. The major difference between the BS and Panje devices, and the Groningen prosthesis, is the patient's role in prosthesis replacement. The BS & panje devices need to be changed regularly by the patient, whereas the Groningen button is self-retaining. This latter feature ensures easier patient instruction and maintenance, because replacement technigues donot have to be practiced. For the aforementioned reasons the Groningen button is considered a valuable addition to the BS prosthesis. The major drawback of Groningen button is its relatively high air flow resistance.

Hilgers J.M., Schouwenburg F.P (1990)

Priorities for further development of the methods and instruments for prosthetic voice rehabilitation have led to the design of a low-resistance, self-retaining voice prosthesis (provox) and an adapted replacement method i.e., The provox voice prosthesis. The results obtained in 79 patients are described by the air flow resistance ranged from 1.6 to 3.8 KPa (mean = 1.9 KPa) and the speech quality was good in 91% of the patients. The self-retaining properties of the prosthesis appeared to be satisfactory. The average device life was more than 5 months.

The now low-resistance, self retaining provox voice prosthesis and the modified replacement method appeared to further improve the results of prosthetic voice rehabilitation after total laryngectomee

In 1991 by Zijlstra, Mahieu, Van lith Bijl and Schutte (1991) developed low-resistance Groningen button. Previously mentioned standard Groningen button had very high opening pressure i.e., 50 to 150 mm H_2O. But this low resistance Groningen button needs very low opening pressure i.e., 3 to 5 mm H_2O.

As per review of literature these are the different types of prosthesis used for voice restoration after laryngectomy. Each prosthesis has its own merits and demerits . The disadvantages of prosthesis has led to the development of new prosthesis. Recently developed like provox, low resistance Groningen button etc have been found to overcome the drawbacks of many other previously mentioned prostheses.

Attempts have been made to develop Fingerless voice Restoration.

Not only voice loss but also the existence of a permanent tracheostoma are severe handicaps of laryngectomy. For that more than 20 years, various surgical techniques for postlaryngectomy voice restoration have been described. Main aim has been to achieve

1. Intelligible fluent speech with good modulation, no aspiration,and no finger to close the tracheostoma.

2. The construction of the respiratory tract without a permanent tracheostoma.

The Blom-Singer tracheostoma valve (Blom -Singer and Hamaker, 1982) developed to eliminate manual occlusion of the stoma enabling "hands free speech". It consists of a curved latex diaphragm that is sensitive to variations in air flow. During tidal respiraion, it remains fully open; as air flow increases for speech, the diaphragm closes against the inner rim of the valve assembly and occludes the tracheostoma, thus diverting air into the oesophagus. The valve automatically reopens when exhalation decreases at the completion of a single speech utterance.

The problem with BS valve was that tracheal secretion allows the tracheostoma valve to stick to the skin of the neck. Later on a tracheostoma valve was developed to eliminate this problem by Herrmann and Kossw-ESKA Herrmann tracheostama valve .
This tracheostama stent is made up of a cannula part and three different types of outer silicon ring to retain the tracheostoma stent. The stent itself is made of very soft silicon and has no magnet. The cannula part of the tracheostoma valve is identical in shape to the tracheostoma stent. The flap valve contains a metal piece located off centre and is controlled by a magnet fixed in the cannula part. The sensitivity of the tracheostoma valve can be adjusted to individual needs by turning the flap valve.

Rubert reported a case who learned to close his tracheal stama by the actual contraction of his platysma muscle.

Primary and Secondary Tracheoesophageal Puncture

Primary T.E.P. is defined as "voice restoration at the time of laryngectomy" and secondary T.E.P. as, "voice restoration at a time subsequent to total laryngectomy".

Singer et. al. (1983) reported a success rate of 63% and Hamaker, Singer, Blom and Daniels (1985) 69% in their series of primary T.E.P. cases. The continued use of primary TEP procedure was limited by the inability of the newly laryngectomized patient to manage a tracheostoma, puncture and prosthesis simultaneously.

Perry, Cheesman, McIvar and Chaltan (1987) reported that 94% of their patients who underment secondary voice restoration were successful by two weeks after surgery but this success rate dropped to 73% by 3 mths. The results in the primary series (perry 1988) were 94% at 3 months after surgery.

Wenig Mulloly, Levy and Abramson (1989) commented that primary and secondary punctures were equally effective in permitting the development of TE speech. They reported that the incidence of complications associated with primary TEP is slightly higher than that seen with the secondary group. Hazarika, murthy, Rajashekhar and Kumar (1990) advocated the use of secondary TEP owing to its high success rate (90%) and the time at the disposal of the patient to learn oesophageal mode of alaryngeal speech if he is interested.

Pharyngo Esophageal (PE) Segment function Assessment

The elements involved in alaryngeal speech production are different from the normal laryngeal speech. Table - 1 shows the different elements involved in alaryngeal speech (both oesophageal and T.E.P.) compare with laryngeal speech

Physical requirement:	Laryngeal Voice	Oesophogeal voice	TE voice
1. Initiator	Moving column of air from lungs	Moving column of air from oesophagus	Moving column fo air from lungs
2. vibrator	vocal cords	PE - segment	PE - Segment
3. Resonator	vocal tract (i.e. Pharynx, nose, mouth)	Vocal tract	Vocal tract
4. Articulators	Tongue, Teeth, lips, soft palate	Tongue, Teeth, lips, soft palate	Tongue,Teeth, lips, soft palate

Adapted from Edels, (1983)
Table - 2 Different elements involved in alaryngeal speech (both oesophageal and T.E.P.) compared with larynyeal speech.

The PE segment or sphincter is vibrator in both oosophagcal and T.E. Speech. Consequently, problems in this region will detrimentally affect both oesophageal, and T.E. speech. Conversely, with good PE function, the main advantage of the TE speech is the increased air reservoir of the lungs allowing louder and more sustained speech.

Seeman (1967) demonstrated that in some patients, air escapes easily through the PE sphincter with an audible sound as soon as the pressure is built upto 10-30 cm of water. However, in same patients, the sphincter fails to relax even at pressures exceeding 100cm of water. This has been attributed to the presence of functional spasm in the pharyngeal musculature. This spasm directs the built-in air towards the stomach instead of pharynx, causing gastric filling and no voice production. This factor has been amply demonstrated in cine-flourogrnphic studies

(Singer and Blom, 1981; Hazarika, Murthy Rajshekhar, 1983). It has been demonstrated that laryngectomees with PE spasm are at risk for TE speech acquisition. Hence its mandatory to establish the presence or absence of the spasm.

Oesophageal Insufflation Test :

The Oesophageal Insufflation Test as described by Blom et. al. (1985) is performed with a disposable system consisting of a special 50cm long, No.14 French latex catheter imprinted with a 25cm marker, a flexible circular tracheostoma housing, adhesives and an insertable stoma adaptor. The patient's nostril is sprayed with a topical anaesthetic and the rubber catheter is transnasally iserted into the oesophagus, until the 25cm marker resides at the nostril. This is to ensure that the tip of the catheter is with in the upper thoracic oesophagus. The proximal end of the catheter is then attached to the adaptor which is inserted into the tracheostoma housing. The patient is required to do an inhalation, light stoma. occlusion and attempt/a/ Phonation on exhalation. The patient is trained till he is used to the procedure. If the patient can sustain phonation without interruption for 8 sec. or longer and can count from 1-15, then he is said to have passed the test. The interpretation is that, he apparently has no pharyngeal constrictor and is considered an ideal candidate for TE puncture and B.S. Prosthesis fitting. If the patient cannot sustain phonation of /a/ for atleast 8 sec or phonate at all, then he is said to have failed the test and needs a pharyngeal myotomy along with puncture for good voice.

Though controversial pharyngeal myotomy is reported to facilitate the development of voice production (singer and Blom, 1981; chodosh, Gian carlo and Goldstein, 1984; Henley, souliere, 1986) An assessment protocol to successfully assess the PE segment function, using video fluoroscopy and radiological tcchnigues in patients undergoing secondary tracheoesophageal puncture has been reported (Cheesman, Knight, McIvor and Perry, 1985, Perry, Cheesman, Mclvor and Chalton; 1987; Mclvor, Evans; Perry and Cheesman, 1990)

AERODYNAMIC AND MYOELASTIC CONTRIBUTIONS TO ALARYNGEAL SPEECH

Normal voice production is an aerodynamic-myoelastic event (Van den Berg, 1958) For example, alterations in respiratory drive and the byproducts thereof (e.g. Glottal volume flow, subglottal pressure) mediate sound production at the level of the Larynx (Atkinson, 1978; Collier; 1975; Ohala, Hirano; 1970). According to Moon and Weinberg (1987) voice source controlled or mediated solely on the basis of aerodynamic influences could operationally be described as a "passive" resonant device. They felt that such a device would not be capable of intrinsic and systematic myoelastic adjacement. Alterations in myoelastic properties of the vocal folds also mediate sound production at the level of the larynx (Atkinson, 1978; Baer, Gay and Niimi, 1976, Collier, 1975; Hirano,Ohala and vennard, 1969, Monsen et. al, 1978) A voice source controlled as a whole, or in part, on the basis of intrinsic and systematic myoelastic adjustments could be described operationally as an " active " voice source.

Laryngectomy necessitates the use of alternate structures for voice production. Two major forms of alaryngeal speech, ocsophageal and tracheoesophageal use the upper oesophageal sphincter as a substitute voice source. The phonatory apparatus used by these speakers is different from that used by normal speakers.

Angcrmcicr and Wcinberg (1981) have stated that "there is no evidence to support the view that laryngectomized individuals are capable of altering the level of muscular activity within the PE (pharyngoesophageal segment) on a systematic basis to pretune control or influence the vibratory rate of this sphincter". Van den Berg and Moolenaar Bizl (1959), Sridecor and Isshiki, (1965) have suggested that oesophageal voice production is an acrodynamically mediated event. Accurate non invasive measurement of source driving pressure and trans-source, air flow rate permitting systematic appraisal of physiological mechanisms underlying production and control of oesophageal voice are now feasible.

Moon and Weinberg (1987) carried out a series of phonatory tasks in tracheoesophageal speakers to assess (a)aerodynamic and acoustic properties of tracheoesophageal voice and (b) aerodynamic and myoelastic contributions to the mediation of fundamental frequency change. Data from their project could be integrated with existing information to highlight some fundamental differences among normal, tracheoesophageal and oesophageal voice production. Sustained vowels produced by normal speakers at comfortable levels typically are associated with source driving pressures ranging between 5 and 10 cm. Water, trans-source airflow rates ranging between 100 and 200 cc/s., and airway resistances ranging from 30 to 45 cm. water/LPS (liters/sec.). Vowels produced at comfortable levels by tracheoesophageal speakers were typically associated with source driving pressures ranging between 20 and 50cm. water, trans-source airflow rates ranging between 110 and 335cc/s, and airway resistance ranging from about 142 to 383cm water/LPS. Moon and weinberg (1987) reported that though directly comparable data during sustained production of vowels by oesophageal speakers were not available to Sridecor and Isshiki (1965) had shown that trans-source air flow rates during oesophageal voicing ranged between 25 and 72cc/S, while Damste (1958) had shown that oesophageal source driving pressure typically ranged between 15 and 60 cm. water.

Moon and weinberg (1987) on the basis of these observations reported that tracheoesophargeal voice production was generally characterised by (a) increased trans source airflow rates, comparable to oesophageal source driving pressure and decreased airway resistances when compared with conventional oesophageal voice production and (b) Comparable to normal tran-source airflow rates, increased source driving pressures and increased airway resistance when compared with normal voice production. These observations, according to them, marked fundamental differences that existed between these three forms of voice production. Both normal and tracheoesophageal voice production use pulmonary airflow, and both are accomplished with a closed tracheal airway.

On the other hand, conventional oesophageal voice production does not use pulmonary air to moves the voicing source and is accomplished with an open tracheal airway.

A major finding in their study was that the tracheoesophageal speakers were capable of varying Fo in association with negatively related variations in trans-source airflow rate. This finding does not confirm the views expressed by Van den Berg, Moolenaar-Bifl and Damste (1958) and Angermeier and Weinberg (1981). Their results, coupled with findings that aerodynamics contributes to TE phonation, are interpreted to suggest that tracheosophageal voice production should be regarded as an aerodynamic myoelastic event. Similarly, the role and airway resistances in alaryngeal voice production has been the area of interest to many investigators and relevant information has accumulated over the recent years.

ANALYSIS OF VOICE

Numerous studies have been done to understands the mechanism of voice in normal laryngeal speakers. A lot of interest has been shown by researcher to understand the mechanism of alaryngeal voice, the mode of communication for laryngectomees. TE mode of alaryngeal voice aided with different prostheses like B.S. prosthesis, panje button, Groningen prosthesis etc., have been studied by few investigators. The studies have concentrated on specific areas, like frequency,duration etc., Exhaustive studies considering all Lhe relevant parameters and their contribution to intelligibility and acceptability are limited. Hence, there is a need to identify the factors influencing the intelligibility of this mode of alaryngeal speech.

Michel and Wendahl (1971) and Hirano (1981) have emphasized the need to use as many parameters of voice as possible in assessing voice and its disorders. Michel and Wendahl (1971) considered voice as a multidimensional series of measurable events and suggested 12 parameters for assessing voice. Other (Imaizumi, Hiki, Hirano and Masushita, 1980, Kim, Kakita and Hirano, 1982), have suggested different parameters to study voice and its disorders. Some of the parameters suggested by these have been used by Nataraga (1986) to find the possibilities of differential diagnosis of dysphonics. These parameters have been reported to be useful in differentiating different types of voice. Similar parameters have been used by Shipp (1967), Rajashekhar (1991), Hariprasad (1992) to study Oesophageal speakers, Robbins ct. al. (1984) Rajashekhar (1991), Hariprasad

(1992) have compared the T.E. speakers with oesophageal and laryngcal speakers in frequency, intensity and temporal measures.

The parameters considered in the present studies were:-

Psychoacoustic parameters

1. Acceptability (ACPTL)
2. Intelligibility (INTL)

Acoustic Parameters :-

Frequency:-

3. Fundamental frequency (Fo) in phonation (/a/, /i/ & /u/)
4. Fo in speech
5. Extent of fluctuation in Fo in Phonation (/a/, /i/ & /u/)
6. Speed of fluctuation in Fo (/a/, /i/ & /u/)
7. Frequency range (FR) in phonation (/a/, /i/ & /u/)
8. Frequency range in speech.

Intensity :-

9. Intensity range (IR) in phonation (/a/, /i/ & /u/)
10. Intensity range in speech
11. Extent of fluctuation in intensity in phonation (/a/,/i/ & /u/)
12. Speed of fluctuation in intensity in phonation (/a/,/i/ & /u/)

Temporal measures :-

13. Maximum phonation duration (MPD) (/a/, /i/ & /u/)
14. Rising time (RT) in phonation (/a/, /i/ &/ u/)
15. Falling time (FT) in phonation (/a/, /i/ & /u/)
16. Vowel duration (VD) of /a:/,/u/, /o:/, /i/ &/e/
17. Voice onset time (VOT) of /p/, /t/ & /k/

Spectral measures (Long term Analysis of the Spectrum)

18. Ratio of intensities between 0-1 KHz & 1-8 KHz (Alpha ratio)
19. Ratio of intensities between 0-2 KHz & 2-8 KHz (Beta ratio)
20. Ratio of intensities 2-5 KHz & 5-8 KHz (gamma ratio)
21. Formant Frequencies (Fl, F2, F3) for /a:/, /u/, /o:/, /i/ & /e/

These parameters were studied to determine their relationship with aerodynamic and physiological characteristics of the vocal mechanism and their contribution towards perception of voice/ Speech. The frequency parameters have been used to access the impact of aerodynamic events on alaryngeal vibratory source (PE segment). The intensity parameters enable assessment of the contribution of pulmonary source of air in TE speakers to loudness and its stability. Temporal parameters determine the effect on pulmanary air on the PE segment. The formant frequencies have been measured to obtain knowledge of the vocal tract configuration, transfer function and the contribution on vowel intelligibility. The spectral measures obtained by LTAS evaluate the quality of speech and presence of noise. All these parameters, singly or in interaction with each other are considered to be affecting the intelligibility, and acceptability of alaryngeal speech. The effect of these parameters on the intelligibility and acceptability of speech in alaryngeal speakers has not been given much importance. Hence, all these parameters have been considered in this study.

The following review would highlight the importance of each parameter in the assessment of laryngeal and alaryngeal speakers.

ACCEPTABILITY OF ALARYNGEAL SPEECH

Clinical utility of any alaryngeal voicing technique lies in its intelligibility and acceptability. Many studies have been done to test acceptability ratings for oesophageal speakers, T.E.P. speakers, speech using artificial larynx. But not many have been carried out to study the acceptability rating of T.E.P. speakers with different prosthesis i.e., comparative study of different prostheses.

The work of Shipp (1967) and Hoops and Noll (1969) have shown that variables such as rate of speech, phonation time characteristics,

high mean fundamental frequency and severity of stomal noise ratings are significantly related to judgements of speech acceptability. Rajashekhar et. al. (1990) in a single laryngectomee case study found that T.E. speech was more accepted than oesophageal because of 1. Increased intensity, and rate, 2.Reduced pauses and extraneous noise and 3. overall better guality Hazarika et. al. (1990) studied the speech proficiency profile of their T.E.P. patient fitted with B.S. voice prostheses. The acceptability of their speech was judged as a scale of excellent, good, fair and poor. From a total of 18 speakers, 8 users rated as "excellent" six as "good" three as "fair" and only one as "poor". It was hence decided to identify those factors which contributed to the acceptability of alaryngeal speech. Rajashekhar (1991) reported that L.P. aided T.E. speakers were more acceptable to the listeners than the oesophageal speakers.

INTELLIGIBILITY OF ALARYNGEAL SPEECH

Comprehensive data about articulatory changes as a result of the removal of the larynx is lacking. There is experimental evidence to support the notion that total laryngectomy does alter articulatory behaviour. Weinberg (1986) opines that total laryngectomy disrupts muscular support for the tongue, brings out major changes in articulatory aerodynamics and alter the vocal tract morphology. Many investigations have been made (Hyman, 1955, Hoops and curtis, 1971, Weinberg, 1980 etc) to study oesophageal speech and found that there is reduction in speech intelligibility when T.E. speakers were compared with oesophageal speakers in similar listening conditions, Singer (1983) noted that T.E. speakers were more intelligible, although the differences decreased in quiet listening conditions.

Tardy-Mitzell, Andrews and Bowman (1985) studied the acceptability and intelligibility of T.E. speech. They observed a mean intelligibility score of 93% in T.E.P. speakers.

Rajashekhar (1991) reported that L.P. aided T.E. speakers were more intelligible than oesophageal spekers. He concluded that T.E. speakers with adequate digital occlusion presented less stomal air leak noise and had higher acceptability and intelligibility rating.

The increased pulmonary driving force permits TE speakers to use fewer pauses so that the flow of their speech is often more natural than that of oesophageal speakers and hence may influence listener's judgements of overall intelligibility in discourse. In this study attempt has been made to determine the speech intelligibility and acceptability of T.E. speakers with different types of prosthesis.

FUNDAMENTAL FREQUENCY (FO) IN PHONATION:-

Fo is the lowest frequency that occurs in the spectrum of a complex tone. In human voice also, -the lowest frequency in the voice spectrum is known as the fundamental frequency. ". . . . .both quality and loudness of voice are mainly dependant upon the frequency of vibration. Hence, it seems apparent that frequency is an important parameter of voice (Anderson, 1961)

Emrickson (1959) is of the opinion that the vocal cords are the ultimate determiners of pitch and that the same general structure of the cords seem to determine the range of frequencies that one can produce. The perception of pitch and measurement of Fo are based on the systematic opening and closing of the vocal folds during the production of voiced speech signals. Hence, when Fo is measured acoustically, the process is actually to count these openings & closing by same method. There are various objective methods to measure the Fo of the vocal fold vibration.

Variation in Fo play an important role in speech and has been studied as itonation. The stduy of Fo has important clinical implications.

Number of studies have been undertaken to spicify the Fo characterstics in alaryngeal speakers. Fo range of oesophageal speakers is too narrow. Average Fo for individual oesophageal speakers exhibit extensive variability - the range in mean Fo extends from approximately 30 Hz to 200 Hz. Hammarberg and Nord (1989) reported that it was diffcult to extract the Fo from oesophageal voice, due to its unusually low value and aperiodic nature. The oesophageal speakers of their series had Fo ranging from 55- 76Hz.

Attempts have been made to extract the Fo in T.E.P. speakers fitterd with B.S. voice prosthesis as follows :

Investigators	Mean Fo(Hz)
1. Singer (1983) 64-81	
2. Robbins et.al (1984)	82.80
3. Blood (1984)	89.3
4. Mac Curtain & Christopherson (1985)	70.(mode)
5. Hammarberg and Nord (1989)	84-125
6. Zanoff et.al. (1990)	100
7. Rajashekhar et.al (1990)	92
8. Rajashekhar (1991)	110.7

Table 3 :- The Mean Fo in T.E.P. speakers reported by different investigators.

Zanoff, Wold, Montague, Kruegers and Drummond (1990) analyzed T.E.P. speech with and without the tracheostoma valve (Singer et.al, 1982) in 9 patients. No statistically significant differences found between the two speaking conditions.

In this study attempt has been made to study Fo in phonation using different types of prosthesis.

FUNDAMENTAL FREQUENCY IN SPEECH [Fo (sp)] :-

An evaluation of the Fo in phonation, may not represent the

Fo used by an individual in speech. Studies have shown that the Fo in phonation and speech are different (Nataraja and jagadeesha, 1984). Hence, it becomes important to evaluate the speaking Fo (SFF). Determination of the speaking Fo requires an adequate speech sample. Using a reading task rather than spontaneous speech has an advantage for comparison between speakers, if the same material is used (Baken, 1987).

Many investigators have studied the SFF as a function of age and in various pathological conditions (Michel, Mollien, Moore, 1965, Murry, 1978, Hirano, 1981, Nataraja, 1986) The SFF is reported to decrease with age upto ....increase in advanced age group, (Hollien and shipp, 1972) Nataraja and Jagadeesha (1984) measured the Fo in phonation, reading, speaking and singing in normal males and females. They observed that the Fo increased phonation to singing with speaking and reading in between.

At present, mean SFF is measured as a part of clinical test (Hirano, 1981) studies measuring the SFF in alaryngeal speakers have been carried out. Only the recent studies have categorized the measure of Fo into that for phonation and make clear cut distinction between the Fo for phonation and speech. The mean SFF of oesophageal and T.E.P. (B.S. voice prosthesis) speakers by different investigators are as follows.

	Mean SFF(Hz)	
Investigator	Oesophageal	T.E.P.
Damste (1958)	67.5	
Hoops & Noll (1969)	65.69	
Blood (1984)	64.6	88.3
Robbins et al (1984)	77.1	101.7
Pindzola & cain (1989)	84.1	107.7
Rajashekhar et al (1990)	68	114
Zanoff et al (1990)		102.50
Rajashekhar (1991)	91.8	136.7

Table 4 - The Mean Fo in speech in T.E. and Oesophageal speaker by various investigators.

The measurement of Fo, both in phonation and speech is important in assessing the neuromuscular development and diagnosis and treatment of voice disorder.

It has been established that the Fo of vowels varies systematically as a function of vowel height Ohala and Eukel, 1978 for America English, Mohr, 1971, for Chinese, German and Russian, Gandour and Maddiesan, 1976, for Thai Specifically high vowels have a higher Fo than low vowels. Various explanations have been offered to account for this intrinsic variations in Fo between vowels.

The source tract coupling hypothesis (Liberman, 1970, Atkinson, 1973) states that coupling between the vocal tract and source occurs when the first formant frequency of the vowels is near the Fb of the source. This results in the increase in Fo for high vowels. In low vowels, coupling doesn't occur due to the first formant being farther away from Fo. The tongue-pull hypothesis (Ladefoged, 1968, Lehiste, 1970) states that as the tongue is stretched or elevated to produce high vowels, a pull is exerted on the larynx altering the tension of the vocal folds and consequently, an increase in Fo. The proponents of this hypothesis have encountered difficulty specifying the precise interconnections between the tongue and the larynx that mediate altered tension of the vocal folds. Ewan (1979 a,b) modified the tongue - pull hypothesis and emphasized compression of soft tissue above the vocal folds during the production of low vowels, rather than pulling or stretching of the tongue during the production of high vowels. The analysis of oesophageal speech support above hypothesis. (Weinberg, 1982,) No reports are available to the present investigator on this in T.E. speakers.

It would be interesting to see whether there is any difference in Fo in speech of T.E. speakers with different types of prosthesis.

INTENSITY:-

Loudness, a perceptual corrolate of intensity is essential for speech to be audible and thus be intelligible. Isshiki (1964, 1965) considered vocal intensity to be dependent on an interaction of subglottal pressure and the adjustment status and aerodynamic at the level of the vocal folds, as well as vocal tract status. The range of intensities at which voice can be produced is a measure of the limits of adjustment of the phonatory system and therefore, has been proposed as a potentially important measure in the assessment of voice (Michel and Wendahl, 1971)

The intensity level of connected speech shows very large fluctuations over short time intervals, because speech contain periods of silence and the intensity is varied for syllable and word stress (Liberman, 1960, Fry, 1955). Further, different phonemes are characterized by different acoustic powers ie., intensity.

The SPL of connected speech in normals, lies in the range of 70dB (Hyman, Lass, Robbins et. al 1981) and in oesophageal speakers reported to be 70 dB SPL (Hyman 1955) and 62.4 dBSPL (Hoops and Noll, 1969) on the average oesophageal speech is produced 6-10dB below that typically found for normal speech. Singer (1983) reported considerably lower intensity in oesophageal speakers compared to T.E.P. speaker. Pine (1983) attributed this to the greater intraoral breath pressure.

Pauloski et. al. (1989) mean intensity (reading in dBSPl) for those conditions were

73.19 - duck bill with valve

73.57 - duck bill without valve

73.74 - low pressure with valve

74.41 - low pressure without valve

This parameter hasnot been considered in the present study. It is known that intensity in speech is affected by several factors like environmental noise, context of speech, hearing sensitivityof the individual. Further, factors involved in recording like Mic mouth distance, sensitivity of the microphone affect this parameter. This parameter requires a relative reference which vary based on the factor mentioned above.

FLUCTUATION IN FUNDAMENTAL FREQUENCY AND INTENSITY IN PHONATION

Presence of small perturbations or irregularities of glottal vibrations in normal voice has long been known through oscillographic analysis of acoustic pressure waves and through laryngoscopic high speed photographic investigations (Moore and Van Leden, 1958) In abnormal vocal production aperiodic laryngeal vibratory patterns have been reported (Carhart, 1938, 1941, Bowler, 1964).

Variations in Fo (period) & amplitude of successive glottal pulses, in particular, are often referred to as "jitter" and "shimmer" respectively. Because of their minute nature, their measurements were time consuming and difficult. Even with recent research their neurophysiological and perceptual significance are not well understood. (Heiberger and Horii, 1982). However, these measures have been useful in describing the voice charactristics of both normal and pathological speakers and used for early detection of laryngeal pathology (Koike, 1973, Zyski, Bull, Mc Donald and Johns, 1984, Liberman, 1963)

Shimmer is defined as "variations of peak amplitude in successive glottal pulses" (Heiberger and Horii, 1982) Shimmer, in any given voice is dependent at least upon the modal frequency level, the total frequency range and the SPL relative to each individual voice (Michel and Wendahl, 1971). During normal voice production, the vocal folds vibrate in a synchronous, quasi-periodic manner in which small cycle-to-cycle variation in frequcney and amplitude of vibration occur. Non pathological speakers appear to have an average jitter of approximately, 1% or less (Jacob, 1968; Hollien et al, 1973, Koike, 1973). Likewise, overall average shimmer has been found to be 0.39 dBSPL for the three vowels /a/,/i/ and /u/.

Studies to investigate the relation between pitch and amplitude perturbations and pathological conditions in the larynx like recurrent laryngeal nerve palsy advanced carcinoma have been studied and concluded that signifacant difference were found compare to the normals (Liberman, 1961, kirn et. al. 1982, Koike 1969, yoon et al 1984) Nataraja (1986) studied the voices of normals and dysphonics and reported significant differences between normals and dysphonics.

' Liberman (1963) proposed an index which he called the perturbation factor which is the percentage of all perturbations egual to or greater than a half milli second (0.5ms) Hoops and No1l (1969) reported a mean perturbation factor of 41.1% in connected speech (Rainbow passage) of 22 oesophageal speakers.

Jitter ratio (JR) a relative measure which takes into account the dependence of absolute jitter size as Fo level is obtained using a formula, proposed by Smith, Weinberg, Feth and Horii (1978)

JR = xj \/xp x 1,000

where, xj = mean jitter in ms &
xp = mean period in ms

Several studies to investigate the pitch and amplitude perturbation in alaryngeal voices have been done. Most of them concludes that jitter ratio is maximum in oesophageal speakers and minimum in normal laryngeal speakers. The T.E. speakers exhibited intermediate level.

Robbins et. al. (1984) obtained the mean jitter, jitter ratio and directional jitter during sustained phonation in groups of laryngeal, oesophageal and T.E. speakers.

	Mean Jitter (MJ)	JR	Directional jitter (DJ)
Laryngeal	MJ = .1	JR = 7.7	DJ = 54.3
	SD = .1	SD = 5.1	SD = 8.6
Oesophageal	MJ = 4.1	JR = 182.5	DJ = 58.7
	SP = 5.2	SD = 97.5	SP = 13.4
T.E.	MJ = .7	JR = 51.4	DJ = 63.4
	SD = .6	SD = 46.8	SD = 9.3

Table 5 :- The MJ, JR, and DJ in normal, Oesophageal and T.E. speakers.

Kinishi and Amatsu (1986) measured pitch perturbation of alaryngeal voices after the Amatsu T.E. shunt operation. They reported mean jiter of 0.07, 0.47 and 0.82 msec and Jitter ratio of 10,30 & 60 for laryngeal, T.E. and oesophageal groups respesctively.

These studies conclude that T.E. speech using exhaled pulmanory air is more stable than conventional oesophageal speech. According to them, the stable air supply (pulmonary) in T.E.P. contributed to the control during sustained phonation.

Pauloski, Fisher, Kempster and Blom (1989) compared T.E. speech produced under 4 prosthetic/occlusion speaking conditions in 12 males and 12 female subjects.

The speaking conditions were :-

1. duck-bill prosthesis with digital occlusion,
2. duck-bill prosthesis with tracheostoma value
3. low - pressure prosthesis with digital occlusion
4. low - pressure prosthesis with tracheostoma value.

The mean directional jitter (%) in these 4 conditions were

70.79 duck-bit) with valve

68.76 duck-bill with digital occlusion

68.57 low pressure with valve

68.98 low pressure with digital occlusion

Zanoff et. al. (1990) compared acoustic & temporal measures in 9 male T.E. Speakers with and without the valve. The mean pitch pertubation in sustained vowel was 9.44% (SD = 7.20) and with the value, 8.56% (SD = 3.84)

Trudeau and Qi (1990) reported a mean jitter, jitter ratio and directional jitter of 1.78 msec, 134.8 and 63.2% respectively in 10 female T.E. speakers. Comparing the values with those for male TE speakers in the study by Robbins et. al. (1984), they stated that the female demonstrated larger mean jitter and jitter ratio . Rajashekhar et. al. (1990) from a study of two modes of alaryngeal speech in a single laryngectomee and reported that the extent of fluctuation in Fo was higher in the oesophageal mode (19 Hz) as compared to the T.E. mode (9.2 Hz). The speed of fluctuation in Fo was 36 in the oesophageal and 14 in T.E. mode. They attributed these higher values in the oesophageal mode to less stability in Fo control during sustained phonation.

Rajashekhar (1991) from a study of 20 L . P . aided T.E. speaker and 20 oesophageal speaker found that extent of fluctuation in Fo was 13.3 Hz in T.E. speaker and 10.4 Hz in oesophageal speakers and speed of fluctuation in Fo was 14.6 Hz in T.E. speakers and 16.5 Hz in oesophageal speakers. The presence of greater values of extent and speed of fluctuations in phonation in both the groups suggested that availability of pulmonary air supply to the T.E. speaker, did not improve the vibratory patterns at the pseudoglottis.

Intensity perturbation :-

Robbins (1984) revealed that both the alaryngeal group demonstrated greater mean shimmer and shimmer SD in their vowel productions relative to the laryngeal speakers. The oesophageal group presented the most deviant values. However, directional shimmer values and SD for directional shimmer were higher for the T.E. speaker than normals. Based on the result they concluded that the difference in anatomic - physiologic mechanisms used by the alaryngeal groups for production of voice were not only different from those employed by laryngeal speakers, but were substantially different from those employed by each other.

Pauloski et. al. (1989) reported lower Shimmer values in T.E. speakers, who used low pressure prosthesis and spoke by digitial occlusion. The directional shimmer (%) in those 4 conditions were

70.52% - duck bill with valve

65.14% - duck hill without valve

67.50% - low pressure with valve

66.89% - low pressure without valve

The female T.E. speaker in the study by Trudean ana QI, (1990) indicated greater amplitude perturbations than the male speakers of Robbins study (1984).

Rajashekhar et. al. (1990) reported that the extent of fluctuation and speed of fluctuation, a gross measure of the amplitude perturbation were greater in the oesophageal mode than the T.E. mode, in a laryngectomee, who proficiently used both these modes.

Rajashekhar (1991) found extent of fluctuation in intensity in phonation of /a/ was 3.3 dB in L.P. aided T.E. speakers and 3.8 dB in Oesophageal speakers and speed of fuluctuation in phonation of /a/ was 6.8 dB in L.P. aided T.E. speakers and 28.4 dB in oesophageal speakers.

The speed and extent of fluctuation in intensity and frequency have been considered to be related to the quality of voice. They are considered to be useful in assessing the quality of voice in alaryngeal speakers also. Hence, it was decided to study these parameters to findout their contribution to the intelligibility of speech in alaryngeal speakers.

FREQUENCY RANGE IN PHONATION AND SPEECH

The patterned variations of speech over linguistic units of differing length (syllables, words, phrases, clauses, paragraphs.), yield the critical prosodic features, namely intonation (Freeman, 1982). In other words, during speech, the Fo varies with time. The difference between maximum and minimum Fo is called the speech frequency range (Hirano, 1981).The mean SD and range of frequency range phonation in a study by Nataraja (1986) were 8.28 Hz, 4.75 & 1-16 Hz respectively. Hudson and Halbrook (1981) - reported mean range of 81.95 to 158.50 Hz in Young male black adults. Nataraja (1986) reported a mean frequency range in speech of 248 Hz, Gopal (1986) have reported a mean of 134 Hz (16-25 years) and a mean of 181.49 Hz (36-45 years) in speech.

Murry and Doherty (1980) reported that the variability in SFF, along with directional and magnitudinal perturbation factors enhanced the ability to discriminate between normal and speaker with the cancer of larynx

Snidecor and Curry (1959) reported a mean Fo range of 13.21 tones in 6 oesophageal speakers. Robbins et. al. (1984) reported a mean Fo range of 5.8 Hz (SD = 1.8) in normal during sustained phonation, 73.9 Hz (SD = 43.2) in oesophageal speakers and 39.9 Hz (SD = 41.6) in TE speakers. The mean Fo range of normal, oesophageal and T.E.P. groups during reading were, 85.9 Hz (SD =18.8), 118.1 (SD = 43.8) and 142.3 Hz (SD = 96.8). They concluded that large Fo range during vowel production was produced by oesophageal speakers, whereas greater Fo range during connected speech was produced by T.E. speakers. Rajashaker (1991) reported mean Fo range of 45 Hz in L.P aided T.E. speakers and 25. 7 Hz in oesophageal speakers in phonation of /a/ and 111.4 Hz in L.P. aided T.E. speakers and 59.6 Hz in oesophageal speakers in speech.

INTENSITY RANGE IN PHONATION AND SPEECH :-

Loudness is in general, the perceptual corrlate of intensity. It refers to the "strength of the sensation received through the ear". Intensity changes are important in every day verbal behaviour, and the extremes in intensity of vocal tones occupy a considerable range, even during conversational speech. Coleman et. al. (1977) reported the average intensity range of phonation (in SPL, re: 0.0002 dynes/cm2) at a single Fo as 34.8 dB for males and 51 dB for females.

Measurement of vocal intensity, as a clinical diagnostic tool has not proved as popular as that of Fo in voice clinics.

Nataraja (1986) reported small variations in intensity in sustained phonation, in normal males.

Singer (1983) reported intensity ranges in 4 TEP patient extended from 20.29 dB. Pauloski et. al. (1989), reported intensity range (vowel phonation) in 4 conditions. They were

10.54 dB - duck-bill with valve
10.05 dB - duck-bill without valve
9.67 dB - low pressure with valve
9.92 dB - low pressure without valve

Rajashekhar (1991) reported a mean intesity range of 13.6 dB in L.P. aided T.E. speaker and 16.4 dB in oesophageal speaker in phonation of /a/ and 34.7 dB in L.P. aided T.E. speaker and 39.1 dB in oesophageal speakers in speech.

Information regarding the intensity range in the laryngeal groups is scanty. The measurement of this parameter............. understanding of the alaryngeal speaker's ability to maintain the intensity and its contribution to the intelligibility.

TEMPORAL MEASURES

MAXIMUM PHONATION DURATION (MPD)

The ability to sustain a vowel to maximum duration provides some objective measure of the efficiency with which a speaker utilizes the respiratory mechanism. (Nejman and Edeson, 1981) This measure has been suggested as a clinical tool for evaluation of vocal function for the past 3 decades. The MPD is considered a good indicator of abnormal tension in the larynx, general status of vocal apparatus, neuromuscular disability and respiratory co ordination. (Gould, 1975, Arnold, 1959, Michel and Wendual, 1971). There are studies reporting data of MPD in normal children adults (Btacek and Sander, 1963; Hirano et. al. 1968) and on children and adults with laryngeal pathology (Sawashima, 1966; Hirano et. al.; 1968;)

There is a lot of disparity among the clinicians about the normative data. As there are a number of variables that affect the MPD. The variables investigated include 1. vital capacity and air flow rate (yanagihara & koike, 1967, Isshiki et al; 1967), 2. vocal pitch and intensity (Ptacek and Sander, 1963, Yanagihara et.al. 1966, Shashikala, 1979), 3. Sex (Ptacek and Sander, 1963, Yanagihara et al; 1966,) 4. Age (Launer, 1971; Rashmi, 1985, Vanaja, 1986; Nataraja; 1986) 5. Height and Weight (Lewis et. al; 1982) 6. Training (Lass and Michel 1969; Sheela, 1974) 7. Position (Sawashima,1966), and 8. Number of trials (Sanders, 1963, Lewis et. al., 1982)

"Norms" for maximum phonaticn time vary from 10 Sec for consonants in children to 30 Sec, in vowels in adults (Arnold, 1955) Normal individuals should sustain a vowel for atleast 15 Sec without difficulty (Van Riper and Irwin, 1957) Fairbanks (1960) reported a duration of 20 to 25 Sec as normal.

The normal values for MPD have been reported by several investigators (Suzuki, 1944; Yanagihara et. al; 1966, Isshiki et. al; 1967, Hirano et. al; 1968, Sheela; 1974, Jayaram; 1975, Vanaja; 1986, Krishnamurthy; 1986, Nataraja; 1986). The average is greater for males than for females. There are studies on MPD in oesophageal and T.E.P. speakers.

Investigator	MPD (Sec) Oeso.	T.E.P.
Baggs & Pine (1983)	4.8	11.0
Singer (1983)	-	22.0
Robbines et. al.(1984)	1.9	12.0
Pindzola and Cain (1989)	1.8	16.4
Sedory et.al. (1989)	1.1	8.5
Omori et. al. (1989)	1.2	14.8
Rajashekhar et.al. (1990)	1.3	10.0
Zanoff et.al. (1990)	_	10.4* 9.2**
Hazarika et.al. (1990)	_	6.32
Rajashekhar (1991)	1.5	7.40

Table -6 The mean MPD in oesophageal and T.E. speakers as reported by various investigators.
* MPD measured with digital occlusion
** MPD measured with tracheostoma Value.

Williams et. al. (1989) in their study of 4 prosthetic/occlusion conditions found that the MPD differentiated between normals and these 4 prosthetic/occlusion conditions, where as these 4 T.E. prosthetic/occlusion conditions were not discriminated among by MPD. They found that MPD was closure to normal with value occlusion than with digital occlusion condition.

Thus, the available literature shows a longer phonation duration during T.E. speech mode. However, the MPD in T.E. speakers is shorter than in normal laryngeal speakers. In this study attempt has been made to note MPD in TE speaker using different types of prosthesis and possible differences among them.

VOWEL DURATION :-

Speech is skilled motor performance. (Kent; 1976). "Timing may be the most critical factor in skilled motor performance". Duration of vowels and consonants are the important aspects of speech. Khozhevnikov and Christovich (1965) considered the durational data as useful in deducing improtant facts regarding the nature and organization of speech production.

Measurements of vowel duration have been made using oscillograms, spectrograms, electrokymographic tracings and computers.

Review of literature indicates that although vowel duration differences are very reliably produced, their role in perception is not predictable. The duration of the preceding vowel is often cited as an important cue to the voicing feature of final stop consonants in english. Nataraja and Jagadeesha (1984) have shown the relationship between FF of voice and vowel duration.

Vowel duration has been studied in the oesophageal speakers also (Weinberg 1976;1982) Robbins, christensen and Kempster (1986) compared the vowel duration of 15 T.E. speakers with 15 oesophageal and 10 normal laryngeal speakers. They reported that the T.E. speakers exhibited the longest durations in producing vowels /i/, /a/ and /u/. The normal speakers had the shortest durations while the oesophageeal speakers had intermediate values. The normal speakers didnot differ significantly from oesophageal speakers and T.E. speakers didnot differ significantly from oesophageal speakers. When compared across groups, the vowel /i/ and /u/ were found to be not significantly different in vowel duration. However, /a/ was significantly longer in duration for all the groups than either /i/ or /u/. According to Robbins et. al. (1986) factors influencing vowel duration in T.E.P. speakers are pulmonary air which is used as a voicing source, large air supply and the effect of the interposed prosthesis, creating an average airway resistance, 3.5 times greater than offered by the normal larynx. This difference in vowel duration in oesophageal and T.E.P. speakers may be due to distinctive aerodynamic components.

Rajashekhar (1991) reported in his study that there is no sig nificant difference in VD of L.P. aided T.E. speakers and oesophageal speakers and also both of these alaryngeal speakers didnot differ significantly from normal speakers.

Vowels are considered as carriers of speech sounds and therefore, the information about the vowel duration in alaryngeal speakers was considered to contribute to the understanding the influence of pulmanory air as the articulatory behaviours and acceptability and intelligibility of speech in laryngectomee.

VOICE ONSET TIME (VOT) :-

VOT is defined as the difference, interms of time, between the release of a complete articulatory constriction and the onset of phonation (Lisker and Abramson, 1967). They stated that the VOT was an useful acoustic cue of the various phonemic categories such as "voiced stop", "voiceless stop" and "voiceless aspirated stop'. They further stated that normal speakers of English systematically varied /p/ /t/, /k/ from /b/, /d/, /g/. Voiced plosives in English normally have a short VOT (less than 20 - 30 msec) and voiceless plosives, relatively long VOT (greater than 50 msec). Lisker and Abramson (1971) stated that VOT is the "single most effective measure for classifying stops into different phonetic categories with respect to voicing".

Gilbert and Campbell (1978) attributed the increased VOT for voiceless stop consonants to greater intraoral air pressure resulting in the increase in the air flow rate and frication at glottis. This glottal frication inhibits the vocal folds from initiating periodic vibration during the production of voiceless stop consonants, thereby delaying VOT. It has also been reported that VOT increases as the place of articulation moved backwards in the oral cavity (i.e.) VOT is greater for velars than for alveolars and in alveolars than labials (Borden and Harris, 1980 Lisker and Abramson, 1967).

According to Wcinbcrg (1982). It is also now well established that laryngectomized patients using oesophageal speech have difficulty achieving voicing contrast between homorgamic stop consonants". Christensen, Weinberg and Alfonso (1978) studied the VOT asociated with production of stops in oesophageal speakers. They reported that oesophageal speakers did effect systematic variation in VOT and that the VOT values associated with prevocalic voiceless stops exhibited lag intervals which were significantly shorter than in normal speakers. They further stated that the VOT characteristics of oesophageal speakers were differentially sensitive to place of articulation.

Robbins, Christensen and Kempster (1986) measured the VOT in voiceless consonants in T.E. speakers and compared it with oesophageal and normal speakers. The VOT was measured from the broad band spectrograms. The VOT results for the laryngeal and the TE speakers differentiated front, mid, and back vowels. The oesophageal group didnot reflect this distinction. The laryngeal speakers had the longest VOT values for /a/ production (/kap/) followed by the T.E. group. The oesophageal speakers had the shortes VOT. The laryngeal and T.E. speakers systematically varied VOT with the change of stop loci from labial to velar positions. The oesophageal speakers performed only marginally in this aspect. Based on above mentioned studies, Robbins et. al. (1986) suggested that the physical characteristics of the neoglottis exert a major influence on VOT productionin alaryngeal speakers. Further, they attributed different VOT effect in alaryngeal groups to aerodynamic capacity, myoelastic and motor control properties of the voicing source and consonant - vowel articulatory loci. Thus, the study of VOT may be useful in determining its effect on intelligibility of speech in alaryngeal speakers. Rajashekhar (1991) reported mean VOT of 27.6 msec for /p/, 24.8msec for /t/ and 33.4 msec for /k/ in L.P. aided T.E. speaker.

FALLING TIME AND RISING TIME IN PHONATION :-

Koike and Van leden (1969) defined rising or "rise time" as "the period extending from the onset of sound to the point at which the envelope amplitude reached the value of steady phonation" Similarly, falling time has been defined as " the period extending from the end of the envelope amplitude with steady phonation to the termination of phonation."

This implied that phonation, requires sometime after initiation to reach a steady level in terms of intenstiy and in its terminal stage, comes to an end gradually. This may be attributed to the need for the subglottal air pressure to build up to a level to make the vocal cords away from the midline and the vocal cords or the laryngeal muscles to make necessary adjustment to produce the voice interms of intensity and frequency. Thus pathological cases, in whom laryngeal and /or respiratory systems are not functioning normally may show differences in rising and falling time.

Hirano (1981) abnormalities of voice, in many pathological conditions will be more apparent during the transitional phase of phonation, including the onset and termination of phonation and speech. There have been attempts to measure the rising and falling time in dysphonics (Kim et.al., 1982, Yoan et. al. 1984; Nataraja,1986)

Rajashekhar et. al. (1990) in a single laryngectomee, proficinet in both the oesophageal and T.E. modes of alaryngeal speech, found a greater rising and falling time in T.E. mode. They attributed the increasedrising time to more pressure required to initiate and sustain the phonation in the T.E. mode and possibly the type of closure achieved at the neoglottis as reflected by the results of the study by Koike et. al. (1969). Greater volume of air enabling sustained phonotion probably increased the falling time. No reports are available regarding these parameters using different prosthesis. Rajashekhar (1991) reported that there is no significant different in both RT and FT in L.P. aided T.E. speakers and oesphageal speakers.

It was considered that the measurement of these two parameters would be useful in understanding T.E. speech using different prosthesis

SPECTRAL MEASURES

LONG TERMS AVERAGE SPECTRUM (LTAS)

There are a number of methods by which speech can be analysed spectrually (Form by and Monsen, 1982) one such analysis procedure takes a time average of the sound pressure level per cycle across frequency. This measurement is referred to as LTAS of speech. LTAS has been used for studies of the human voice source. The speech signal represents the product of sound source and the vocal tract transfer functions. The vocal tract transfer function (differs from different sound segments, but in the averaging process, the short term variations due to the phonetic structure will be averaged out and the resulting spectrum can be used to obtain information on the sound source (lofgvist and Mandersson, 1987)

The measurement of LTAS of speech is made by passing the speech energy through series of bandpass filters and interpreting the energy at the out put of each filter. These average values are then plotted to arrive at the visual representation a smoothed plot by the envelope of the power spectrum of the speech. (Form by and Monsen, 1982). The analysis can be made of readings of a standard text in order to further minimize variations due to phonetic structures.

LTAS has been employed to study the disorders of Speech production (Frokjaer-Jenes and Prytz, 1976, Wendler et. al. 1980, Mahieu et. al. 1986)

Denes and Pinson (1963) stated that the speech power is greatest betueen 100 - 600 Hz where the energy of the Fo of the voice and the first format overlaps. It drops off with increasing over around 600 Hz such that at 10,000 Hz the level is approximately 50 dB below the peak levels measured at low freqency. According to fritzell, Hallen and Sundhery 1974 in normal voices the amplitude of source spectrum partially decreases approximately, by 12 dB/octone provided that the vocal folds can close the rima glottidis efficiently.

Different investigators have employed different methods of obtaining LTAS. Weinberg et. al. (1980) obtained LTAS using FFT competeing spectrum analyser. Kitzing (1986) obtained LTAS by means of B and K signal analyser 203. Hammerberg et. al. (1984) fed recorded speech material of 40 Sec duration through 51 bandpass filters, each 250 Hz wide. The pre emphasized level of each channel was avereged by a computer and was plotted on a frequency intensity diagram. Wandler et. al. (1986) analyzed the Tape recordings of on going speech by means of a real time analyzer, using 25 1/3 octane filters in the area of 63 Hz to 12.5 KHz in combination, with an average NTA 512.

The spectra for group speech are generally comparable both with in and across languages (Fant, 1973}. However, the general shape of the spectra may alter depending upon the experimental variables. The most salient variables are, age (Niemoeller et al 1974), sex of the speaker (Benson and Hirsh, 1953), the analysis band widths (Stevens et.al. 1947); and vocal effort (Brandt et.al. 1969). LTAS measured for individual speakers according to Tarnoczy (1956) are highly dependent upon the personal characteristics of speakers such as vocal effort,pitch, timber, articulation and speed of utterances.

Frokjaer-Jensen and Prytz (1976) used the ratio of energy below and above 1 KHz and named it as alpha parameter. According to them, "because the amplitude above 1 KHz is normalized relative to the amplitude below 1 KHz, alpha is independent of the microphone distance, amplitude levels etc. ''

Hammerberg et.al. (1934) measured the level of the fundamental, the peak amplitude in frequency band 400-600 Hz, the spectral level at 1-5 & 5 KHz respectively and the peak amplitude in the frequency band 5-10 KHz. They then used the difference between the peak level in the 400-600 Hz and other levels as a measure of spectral tilt.

Nataraja (1986) studied 2 spectral parameters in the voice of dysphonics

1. The ratio of intensities between 0-1 KHz and above 1-5 KHz named AA

2. Ratio of intensities of harmonics and noise in 2-3 KHz, name AC.

Kitzinq (1986) discussed several measures that correlated with perceptual judgements of sanarity and strain. The study indicated that a) the ratio of energy by and above 1000 Hz b) the spectral slope in first formant region, and c) the ratio between the level of the fundamental the spectral level in the region of the first formant, as useful measures.

Lofgvist and Mandersson (1987) made 2 measurements on the calculated LTAS.

1. The ratio of energy between 0-1 KHz to 1-5 KHz :- According to them, the ratio of energies between 0-1 KHz to 1-5 KHz provided a measure of the overall tilt of the sound spectrum. A high value of this ratio indicates that the fundamental and the lower harmonics dominate the spectrum which thus fall off rapidly. A low value of this ratio show, on the other hand, that the sound spectrum has a lower spectral tilt. These 2 conditions correspond, ideally, to hypofunctional and hyperfunctional voice.

2. Measurement of the energy between 5-8 KHz :- A high level of energy at these frequencies can be associated with noice components of the source in a hypofunctional voice (Yanagihara, 1967)

LTAS has been used to study the normal and pathological voices.

Rashmi (1985) made an attempt to study the ratio of intensities below and above 1 KHz in the spectra of vowel /i/. She obsenced a lesser energy level above 1 KHz as compared to below 1 KHz. Gopal (1986) lesser intensity above 1 KHz than below 1KHz for both males and females in the age group of 16-55 Years.

LTAS measurements have been attempted in pathological cases, to assess the improvement after treatment (Fritzell et. al. 1974), to correlate LTAS features with perceptual factors (Gauffin and Sundberg, 1977), to differentiate degree of hoarseness (Wendler, Doherty and Hollien, 1980) Hartman and Cramon (1984), Dejonckere (1986), Nataraja (1986) and Balaji (1988) using LTAS in dysphonics, reported higher intensities or acoustic energy than normals in frequencies above 1 KHz.

There are some studies on LTAS of alaryngeal speech. According to Weinberg et. al. (1980) the average spectrum for oesophageal speech was characterized by a flattered spectral envelope, i.e., there was greater relative amplitude in the high frequency components compared with that measured for normal speech. This finding conforms with earlier preliminary observations made by Horii and Hughes (1972)

Hammarberg and Nord (1989) on the basis of spectral analysis of a T.E. speaker and one with servox device reported that alaryngeal voices had weaker fundamental than first formant, irrespective of the total intensity.

Rajashekhar et. al. (1990) subjected speech samples of 20 Sec duration of a single laryngectomee in both the oesophageal and T.E. modes and obtained the ratio between the mean intensities below and above 1KHz (alpha ratio). In the oesophageal mode, the energy above 1KHz was higher than below 1KHz. In the T.E. mode, alpha ratio approximated normal values. Concluded that the higher energy at high frequencies indicated noise components in the oesophageal mode.

Rajashekhar (1991) reported that L.P aided T.E. speakers achived significantly higher gamma ratio than oesophageal speakers. The LTAS results reveals greater energy levels in the higher frequency range for both T.E. and oesophageal speakers when compare to normals.

Qi and Weinberg (1991) commented that LTAS of speech reflected spectral properties of many different speech sounds, thus making the specification of the origin of these differences difficult. Their comparisons between normalized spectral energy with in a selected high frequency range revealed that energy with in this frequency range for vowels produced by T.E. speakers here significantly higher than normal speakers. The formant of normal and T.E. speakers were similar, there was no reason to predict a change in radiation characteristics as a function of the larynx removal. Hence, they attributed the group difference in the spectral slope of vowels to altered source properties. Based on this, they suggested that the origin of the differences in LTAS between normal and oesophageal speech can, in part, be attributed to fundamental differences in acoustical properties of vowels and voiced components of speech.

FORMANT FREQUENCIES :-

The acoustic results of vocal fold vibration is termed the source function and the acoustic result of a certain vocal tract shape and length, the transfer function. The output at the lips is a product of these two functions (plus an effect of sound radiation at the lips)

The resonances of the vocal tract, depicted as broad bands of energy in a spectrogram are known as formants. Fant (1957) defines it as a single energy maximum. The transfer function for vowels refers to the control of the formant pattern by the shape of the vocal tract. Angelocci, Kopp and Holbrook (1964), state that the formant frequency is an important acoustic correlate of the vowel quality and its phonemic identity. The position of the third formant provides less information with respect to vowel differentiation than the first and second formants. The Fl decreases in frequency as pharyngeal enlargement accompanies tongue elevation, and it increases in frequency when the constriction moved back in the vocal tract. F2 is high in frequency when the oral cavity is constricted and low in frequency when it is more open or elongated. Relative formant positions tor a particular vowel are similar tor men, women, and children, but the natural resonant frequencies are higher for smaller vocal tracts. Levitte (1978) suggested that the vowels are differentiated by the ratio of the first and second formant frequencies, i.e., the F2/F1 ratio.

Little difference between the vowel formant frequencies of normal and oesophageal speakers. (Shilling and Binder, 1926; Luchsinger, 1952 as cited in Damste, 1958). In contrast, the studies of Rollin (1962) on English and Kytta (1964) on Finnish speaking laryngectomees showed that vowel formant frequencies for oesophageal speakers were generally higher than those for normal speakers. Rajashekahr (1991) reported higher formant frequencies in oesphageal speakers than L.P. aided T.E. speakers.

No other reports on the formant frequency characteristics of T.E. speakers are available to the investigator. Since the T.E. speakers also have an altered vocal tract due to surgical extirpation of the larynx similar to the oesophageal speakers, elevated vowel formant frequencies are expected.

In this investigation, this has been studied in T.E. speakers using different prosthesis.

COMPUTER ANALYSIS OF ALARYNGEAL SPEECH:-

In recent years, a number of mathematical techniques of speech analysis using computers have been developed and utilized to extract sound source and resonance characteristics of speech. These include the cepstrum method, co-variance and autocorrelation methods, the PARCOR method, the linear prediction method, and the inverse filtering method, to name a few (no11, 1964, markel and Gray, 1973). The method permit researchers to extract from the time domain speech wave form, voice FO, harmonic, amplitudes, formant frequencies, intensity and the long-time and short-time spectrum of connected speech. High fidelity of these methods has been demonstrated not only by the close agreements of their results with traditional spectrographic and oscillographic results, but also by highly intelligible synthesis results.

In spite of their potential as a diagnostic and evaluative tool, the computer methods have not been applied extensively to analysis of alaryngeal speech. Acoustic analysis of alaryngeal speech has been most frequently conducted using traditional spectrographic and oscillographic methods. Most computer techniques, developed and tested using normal speech, often required modifications to handle specific acoustic parameters of interest unique to alaryngeal speech analysis.

Review of the literature revealed few studies of computer applications for the analysis of alaryngeal speech (Horii, 1982; sedory et. al., 1989; Pauloski et. al., 1989; Trudeau and Qi, 1990, Rajashekahar et. al. 1990, Rajashekhar, 1991) Horri (1982) advocates the exploration of the feasibility of both computer and anolog methods to enhance diagnostic, rehabilitative and evaluative procedures for laryngectomees.

The review of literature, thus shows that acoustic temporal and spectral parameters have been studied in normal, oesophageal and T.E. speakers further, studies of acceptability and intelligibility in these laryngeal and alaryngeal speakers has been done. Now, with in T.E. speakers many different types of prosthesis have been used. There is a need to compare these different types of prosthesis by studying different parameters like acoustic, temporal and spectral and also an acceptability and intelligibility ratings.

Therefore, the present study to find out the intelligibility and acceptability, and to carryout study on the acoustic, temporal and spectral parameter of T.E. speakers using different types of prosthesis and to explore their relative contribution to the acceptability and intelligibility has been found essential.

****

METHODOLOGY

The aim of this study was to :

1. Determine the acceptability and intelligibility of T.E. speech with different types of prosthesis, i.e., B.S. Duck-bill, B.S.low pressure and Indian prosthesis.

2. Acoustic analysis of the T.E. speech with different types of prosthesis

Subjects :

Five subjects who had secondary T.E.P. having undergone larngctomy earlier were selected for the study. All of them were screened for hearing ability and neurological conditions. Their purctone theresholds in the speech freguencies were with in normal limits. They had no other speech problem. Details about each case is shown in Table - A.

Case No.	Age/Sex	Surgical procedure	Type of prosthesis used after operation	Time post T.E.P. (Months)
1.	58/M	Laryngectomy + 2° T.E.P.	Duck-bill prosthesis	18
2.	56/M	Laryngectomy + 2° T.E.P.	Low-pressure Prosthesis	12
3.	51/M	Laryngectomy + 2° T.E.P.	Low-pressure Prosthesis	24
4.	49/M	Laryngectomy + 2° T.E.P.	Duck-bill	8
5.	57/M	Laryngectomy + 2° T.E.P.	Low-pressure	10

Note :- 2° = Secondary T.E.P.

Table A : Showing the Details of the subjects used for the study.

All of them had T.E.P., prosthesis fitting and speech services at the same center (KMC Hospital Manipal). The T.E.P. was done by a Head and Neck surgeon. The selection of the prosthesis and speech services were provided by a speech pathologist. All the subjects used digital (finger) occlusion for T.E. speech production.

The other group consited of normal laryngeal speakers matched for age and language with the alaryngeal speakers. They didnot have any speech voice or hearing impairment. The age of this group ranged 35 to 51 years with a mean of 44.2 years.

Data Colletion

The speech samples of all the subjects were recorded individually in a sound treated chamber. Recordings were made on hi-bias metal cassettes using a professional stereo, cassettes using a professional stereo cassette deck (Akai CS - M4) and a AKG -D 222 dynamic cardioid microphone with a flak frequency response from 50- 15,000 Hz. The microphone-to-mouth distance was approximately 15 cm for all the subjects. Recording was done under three conditions, i.e.,for each laryngetomee all the patients were made to use

1. B.S. Duck-bill prosthesis
2. B.S. Low pressure prothesis
3. Indian (HR) prosthesis

No patient complained of any discomfort with prosthesis that he was made to use during recording.

All subjects were required to perform the following tasks, which were recorded for further analysis.

1. Phonation of Vowels :- The normals were asked to ``have a deep inhilation and then say /a/ as long as possible without any break in between''. The T.E. speakers were instructed to ``inhale deeply, close the puncture with the finger and then say /a/ as long as possible without removing the finger. This was demonstrated.

Three trials of /a/ were recorded. Similarly three trials of /i/ and /u/ were recorded for all the subjects.

The recorded samples of vowels /a/, /i/ and /u/ were used for measuring the following parameters

a. Mean Fo, b. extent and speed of fluctuation in Fo, c. Frequency range, d. extent and speed of fluctuation in intensity, e. intesity range, f. maximum phonation duration (MPD), g. rising time, and h. Falling time.

2. Speech Sample :- The subjects were asked to read three meaningful but non-emotional kannada sentences 1. / Idu pa : pu/
n
2. /Idu ko : ti/ 3. /Idu kempu baṇṇa/. Each subject was required to repeat these sentences thrice and the recordings were done.

These recordings were used to obtain the following parameters :

a. Fo in speech, b. frequency range in speech, c. intensity range in speech., d. VOT (/p/ /t/, /k/), e. Vowel duration, (/a:/, /u/, /o:/, /i/ and /e/), and f. Fl, F2, F3, in /a:/, /i/, /o:/, /u/ and /e/.

3. Reading a list of words :- The subjects were required to

read a set of 20 most familiar words in Kannada chosen from the test material used at the department of speech sciences, AIISH, Msyore, India for routine diagnastic purposes from the list of words, (Appendix__HI..), 20 words were randomly selected for each subject. The recorded speech samples were used to measure the intelligibility of the subjects.

4. Reading a passages :- To read standardized passages in Kannada developed and routinely used in department of speech science, AIISH, for speech and voice evaluation. The subjects were instructed to ``read the passage at your comfortable loudness and rate.'' This speech sample was used for the measurement of a. LTAS measurements (alpha, beta, and gamma ratios), and b. acceptability.

Analysis of speech and voice :-

The analysis involved the follwoing equipment :

1. Tape deck to play the recorded speech samples.
2. Antialiasing filter (low pass filter having cut off frequency at 3.5/7. 5k)
3. A-D/ D-A converter (Sampling frequency of 8/16KHz, 12 bit)
4. Personal computer - At Inter 80386 microprocessor with 80387 Numerical data processor.
5. Software developed by voice speech systems, Bangalore
6. Amplifier and speaker.

Procedure for Analysis :-

The recorded phonation and speech samples of each subject were digitized at the rate of 8 KHz using 12 bits VSS date I/P and O/P card by feeding the signal from tape deck to the speech interface unit through live feeding . The digitized samples were stored on hard disk/floppies for further analysis.

The following parameters were obtained from the analysis of digitized smaple of vowels /a/, /i/ and /u/ using ' INTON ' programme. Programme ' INTON ' is based on LPC -autocorrelation method to obtain Fo. It is then processed further to provide the following parameters.

FUNDAMENTAL FREQUENCY IN PHONATION (Fo) :

The Fo of three trials of /a/ was averaged and then considered as the mean Fo in phonation for /a/. Similarly, the mean Fo in phonation for the vowel /a/, /i/, and /u/ were obtained for all the subjects of the four groups.

FUNDAMENTAL FREQUENCY IN SPEECH [Fo(Sp)] :

Nine readings (3 sentences x 3 trials) for mean Fo of speech for each subject were averaged.

EXTENT AND SPEED OF FLUCTUATION IN Fo IN PHONATION
(Ex.F.F./Sp. F.F.)

The fluctuation in frequency was defined as the variations +3Hz and beyond in Fo. The extent of fluctuation in frequency was defined as the means of fluctuations in Fo in phonation of one second. The speed of fluctuation in frequency was defined as the number of fluctuation in Fo in a phonation of one second. The extent and speed of fluctuation for 3 trials of /a/ were averaged and the value considered as the extent and speed of fluctuation for /a/). The extent and speed of fluctuation in Fo for the vowels /a/, /i/ and /u/ for subjects of all the four groups were obtained. .pa

EXTENT AND SPEED OF FLUCTUATION IN INTENSITY IN PHONATION (EX.F.I./Sp. F.I.) :

Fluctuation in intensity was defined as the variations +3dB and beyond in intensity. The extent of fluctuation in intensity was defined as the means of fluctuations in intensity in a phonation of one second. The speed of fluctuation in intensity was defined as the number of fluctuations in intensity in a phonation of one second. This was calculated for vowels /a/, /i/ and /u/ for all the subjects of all the four groups.

FREQUENCY RANGE IN PHONATION (FR) :-

The difference between the maximum and minimum Fo in phonation was considered the frequency range in phonation. Three values of ranges were obtained for /a/ using all the three recordings of /a/ of each subject. The maximum of the three was considered as the frequency range for /a/ for each subject. Similarly, the frequency range for /i/ and /u/ for each subject were obtained for all the four groups.

FREQUENCY RANGE IN SPEECH [FR (Sp)] :-

The difference between the highest and lowest frequency in the utterance of test sentence provided the frequency range in speech for that sentence. The maximum of the nine values was taken as the frequency range in speech for that subject. Thus, the frequency range in speech for all the subjects of the three groups were obtained.

INTENSITY RANGE IN PHONATION (IR) :-

The difference between the maximum and minimum intensity in phonation provided the intensity range in phonation. The maximum of the three trials of /a/ was considered as the intensity range for /a/. Similarly, the intensity range for /a/, /i/ and /u/ for each subject were obtained.

INTENSITY RANGE IN SPEECH [IR (Sp)] :-

The difference between the maximum and minimum intensity in speech provided the intensity range in speech. The intensity range for nine sentences were obtained for each subject. The maximum of the nine values was taken as the intensity range in speech for that subject and similarly for other subjects.

RISING TIME AND FALLING TIME IN PHONATION (RT/FT) :-

The rising time was defined as the time reguired for an increase in intensity from o dB to the begining of the steady level (at least for 50 msec.) of the intensity in the initial portion of the phonation.

The falling time was defined as the time required for intensity to decrease from the steady level (at least for 50 msec) to o dB in the final protion of the phonation.

To measure the rising time, the initial protion of the phonation of the difitized vowel /a/ was processed using the computer programme 'INTON' and the display was obtained on the screen. Then, using the curser, the time at the begining, ie., o dB and the time at the starting point of steady protion of intensity were noted. The difference between the two readings provided the rising time.

Similarly, the difference between the time at the end of the steady portion of intensity and the end provided the falling time. The RT and FT for all the three samples of /a/, /u/ and /i/ were determined and the average of the three values was taken as RT and FT.

LTAS:-

The programme 'LTAS' was used to obtain long term average spectrum and its derivatives. Speech sample of 10 seconds duration each, totally of 30 or 40 seconds was submitted for spectral analysis. The signal was low pass filtered at 7.5 KHz using an antialaising filter and digitized at a rate of 16 KHz. The digitized signal was analyzed in blocks of 50 ms duration with 20 msec resolution. A 1024 point FFT analysis was made. The following parameters were derived from the analysis of samples of each subject :

a) Alpha ratio (Ratio of intensities between 0-lKHz and l-8KHz)

b) Beta ratio (Ratio of intensities between 0-2KHz and 2-8KHz)

c) Gamma ratio (Ratio of intensities between 0-lKHz and 5-8KHz)

Thus Alpha, Beta and Gamma ratio for all the subjects were obtained.

The digitized samples of /Idu Pa:Pu/, /Idu Ko:ti/, and /Idu kempu banna/ were subjected to spectrographic analysis for measuring following parameters using the programme 'SPECTROGRAM'. [Broad band spectrogram (300Hz filter) display of 0-4KHz]. The parameters are

a) Fl, F2, F3 for vowels /a:/, /u/ (as in pa: pu) /o:/, /i/ as in ko : ti) & /e/ (as in Kempu) b. Duration of above mentioned vowels /a:/, /u/ , /i/ /o:/ and /e/c. VOT for /p/ (as in pa: pu) /t/ and /k/ (as in Ko : ti)

Formant Frequencies (Fl, F2, F3) :-

The first three formants (Fl, F2, F3) for each vowel /a:/ , /u/, /o:/, /i/ and /e/ were measured directly from the spectrogram display with sectioning on the screen of the computer. Formant frequency estimates were made by measuring the mid point of the visible dark bands of energy appropriate to the first three vowel resonaces. The measurements were made at a comparatively steady state portion of the vowel.

VOWEL DURATION (VD) :-

The vowel duration (msec) for each vowel /a:/, /u/ /o:/, /i/ and /e/ were measured from the spectrogram display. The measurement criteria for vowel duration were based on suggestions by Peterson and Lehisk (1960), i.e., the vowels were identified on the spectrogram and the duration from the onset of phonation indicated by the initial periodic striations of the first formant to the last vertical striation associated with the second formant were considered as duration for each vowel.

VOICE ONSET TIME (VOT) :-

VOT (msec) of /p/, /t/ and /k/ from /pa:pa/, /ko:ti/ were measured using the definition given by Lisker and Abramson (1967) i.e., the time interval between the burst (or brief interval of high intensity noise) that marks release of the stop closure and the onset of quasi-periodic pulsing that reflected laryngeal vibration was the VOT.

MAXIMUM PHONATION DURATION (MPD):-

The MPD has been defined as the duration for which an individual can sustain phonation. The MPD was measured by using a digital stop watch. The MPD was determined for 3 trials of /a/ and the longest of 3 trials was considered the MPD of /a/ for that subject. Similarly, the MPD for all the vowels were obtained for the subjects of the four groups.

INTELLIGIBILITY (INTL):-

Five speech and Hearing post graduates who were proficient in kannada served as judges. The test material was played to them from a tape recorder.

The judges were instructed to "write down the words on the sheet of paper, as you hear them". You can adjust the volume of the tape recorder to your comfortable loudness level. Blank may be drawn for The word that are not intelligible to you. The intelligibility score was computed as percentage [(no. of words correctly identified/20)x lOO].

Intelligibility scores provided by all the five judges were averaged and that was considered as the intelligibility score for each subject. Similarly, INTL score for all the subjects of four group was determined.

ACCEPTABILITY (ACPTL) :-

The judges selection was similar to INTL scoring. The recorded material was played through a tape recorder and the acceptability rated on a five point scale (1 being the most accepted and five the least) The judges were instructed to "rate the speech of the samples that you hear, as a five point scale with one for most acceptable and five for least acceptable speech". The ratings made by all the five judges were averaged and that was taken as the acceptability score for that subjects. Thus, the acceptability for the subjects of all the four groups was determined.

Thus, the values for all the 23 parameters for all the subjects of four groups were obtained.

****

RESULTS AND DISCUSSION

The purpose of the present study was to

1. Determine the acceptability and intelligibility of T.E. speech with different types of prosthesis ,ie., Duck-bill B.S. prosthesis, low pressure B.S. prosthesis and an Indian prosthesis.

2. Acoustic analysis of the TE speech with different types of prosthesis.

As stated earlier, 19 acoustic parameters and 2 psychoacoustic parameters were studied.

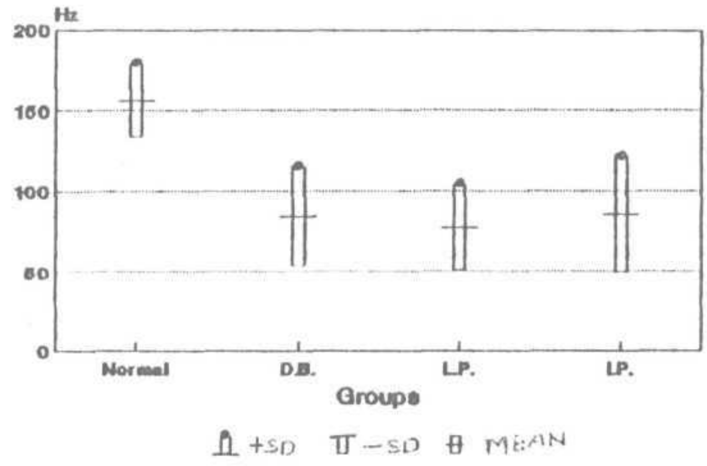
The results and discussion regarding each parameter studied are presented here.

1. FUNDAMENTAL FREQUENCY IN PHONATION (Fo)

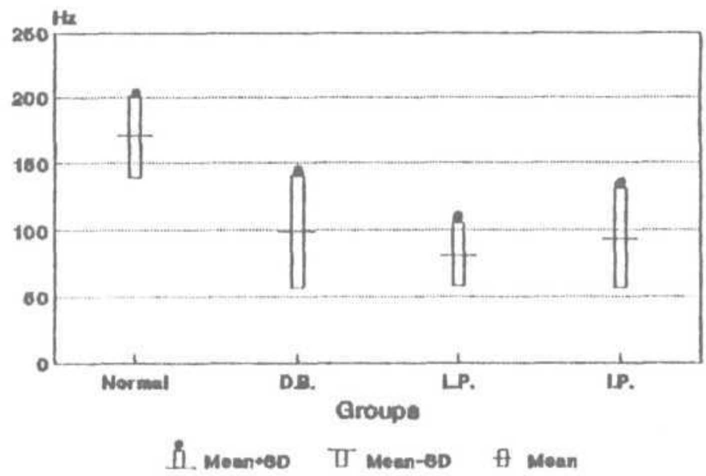
Fo in phonation of /a/, /i/ and /u/ for normals and T.E. speakers with duck-bill prosthesis (D.B.), low-pressure prosthesis (L.P.), and an Indian prosthesis (I.P.) are presented in Table-1 and Graphs-l,2,and 3.

Group		Mean (Hz)	S.D.	Range (Hz)
Normal	/a/	156.4	22.63	128-171
	/i/	170.4	31.18	135-200
	/u/.	166.4	31.15	116-195
D.B.	/a/	84.57	30.38	43-125
	/i/	98.84	41.98	53-156
	/u/	90.05	38.32	46-154
L.P.	/a/	77.69	26.21	44-123
	/i/	81.50	23.33	58-124
	/u/	85.45	35.42	45-159
I.P.	/a/	85.47	35.6	42-127
	/i/	93.67	37.32	52-143
	/u/	99.27	40.9	55-150

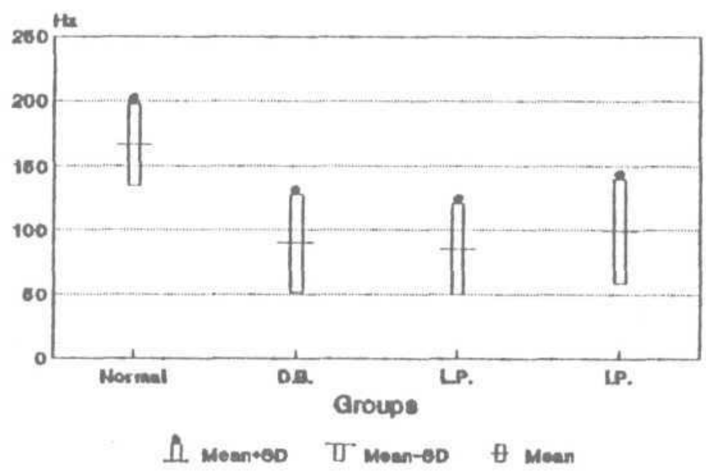
/Table-1 :- The mean,S.D. and Range of Fo (Hz) in phonation of /a/ /i/and /u/ for Normal, D.B., L.P. and I.P. groups.



Graph-1: MEAN FO FOR PHONATION OF /a/



Graph-2:MEAN FO FOR PHONATION OF /i/



Graph-3:MEAN FO FOR PHONATION OF /u/

Study of Table-1 and Graphs-l,2,and 3 reveals the difference between normal and T.E. speakers groups in Fo of /a/, /i/ and /u/. The T.E. speakers demonstrated lower mean Fo than normal laryngeal speakers for all the three vowels. Normal group demonstrated less variability (SD) than the T.E.P. group. Among the T.E.P. group, less variability was seen in L.P. group than in D.B. and I. P. group. The range in Fo for T.E. P. groups were larger than laryngeal group (116-200). Among the T.E.P. group, L.P. (44-159) demonstrated the greatest range in Fo than D.B. and I.P. group.

The mean Fo in phonation of /a/ for T.E. speakers (D.B. or L.P.) of this study were similar to the reports of some studies but lower than study done by Rajashekhar (1991), as shown in Table- 2.

Investigator	Mean Fo (Hz)	
Singer (1983)	64-81	
Blood (1984)	89.3	
Robbins et.al.(1984)	82.8	
Mc curtain & Christopherson (1985)	70.0	
Rajashekhar et.al.(1990)	92	(L.P.)
Zanoff et.al.(1990)	100	
Rajashekhar (1991)	110.7	(L.P.)
Present study (1993)	84.57	(D.B.)
	77.69	(L.P.)
	85.47	(I.P.)

Table-2 :- The Mean Fo (Hz) in T.E. speakers reported by different investigators.

In both-normals and T.E.P. groups- The mean Fo in phonation of /i/ and /u/ were higher than in /a/. In normal and D.B. groups mean Fo of /i/ was higher than IuI, but in L.P. and I.P. mean Fo ..... was higher than /i/. Wilcoxon test for matched pairs.

(paired T-test) was done (Table-31). Significant difference in normal and T.E.P. groups in Fo in phonation was observed. With in T.E.P. groups ,significant difference was observed between D.B. vs L.P. in Fo in phonation of /a/, /i/, but not on /u/ .No significant different was observed between L.P. vs I.P. ,D.B.vs I.P.except in phonation of /i/ in D.B. vs I.P. which was significant statistically. Significant difference was seen in D.B.vs L.P. condition , but not P (Notein D.B. vs l.P. and L.P. vs 1.P. (Note:- Out of 3 vowels , if 2 showed significant difference then only it was considered as significant difference across that condition) .The increase of mean Fo in D.B. group may be due to high airflow resistance associates with the D.B. prosthetis , where as low mean Fo in L.P. group may be due to low airflow resistance with L.P. prosthesis.

The hypotheses stating that "there is no significant difference in terms of Fo in phonation between

1. Normals & T.E.P. speaker (with D.B., L.P. & I.P.) rejected.
2. D.B. aided and L.P. aided T.E. speech rejected.
3. B.S. aided and I.P. aided T.E. speech accepted.
4. L.P. aided and I.P. aided T.E. speech accepted.

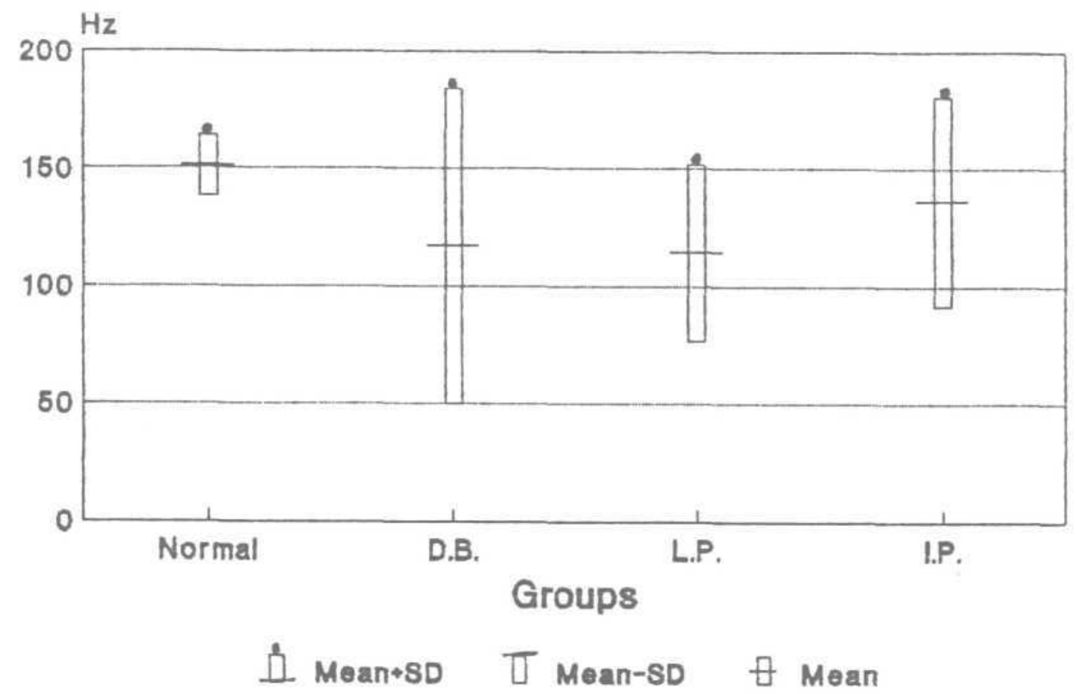
2. FUNDAMENTAL FREQUENCY IN SPEECH (Fo (sp))

The Fo in speech for normals and T.E. speakers with D.B., L.P. and I.P.prosthesis are depicted in Table - 3 and Graph-4.

Group	Mean	S.D.	Range
Normal	151.2	12.75	136-117
n.rt.	117.in	67.41	42-235
L.P.	114.39	37.74	59-169
T.P.	116.4R	44.56	62-179

Group Mean S.D. Range
Normal 151.2 12.75 136-117
n.rt. 117.in 67.41 42-235
L.P. 114.39 37.74 59-169
T.P. 116.4R 44.56 62-179

Table -The Mean, S.D. and Range of Fo (Hz) in speech for normal, D.B., L.P. and I.P. groups.



Graph-4:MEAN FO FOR SPEECH

As a group, T.E. speakers (with D.B., L.P. & I.P.) showed higher Fo in speech than in phonation of vowels. The normal group however showed lower mean Fo in speech as compared to the vowels.

Study of Table - 3 reveals that T.E. speakers had lower Fo in speech than normals. Among T.E.P. group, I.P. aided T.E. speakers showed higher mean Fo in speech than L.P.and D.B. aided T.E. speakers. Normal group demonstrated less variability (S.D) than T.E.P. group. Among the T.E.P. group less variability was seen in L.P. aided group than D.B. & I.P. The range in Fo of speech for T.E.P. group were larger than normal group (136-171). Among the T.E.P group, D.B. (42-235) had the greatest range in Fo than L.P. and I.P. group.

The mean Fo in speech for T.E.P. group were compared with the other reports (Table - 4)

No significant difference was observed between normal and T.E.P. group except normal and L.P. aided T.E. speakers, which showed significant difference. This suggested that T.E. speakers attained speaking Fo similar to laryngeal speakers, in spite of using neoglottis for voice production.

Investigator	Mean Fo (Hz)
Blood (1984)	88.3
Robbins et. al. (1984)	101.7
Pindzola & Cain (1989)	107.7
Rajashekhar et. al. (1990)	114.0 (L.P)
Zanoff et. al. (1990)	102.5
Rajashekhar (1991)	136.7 (D.B)
Present study (1993)	117.18 (D.B)
	114.39 (L.P)
	136.48 (I.P)

Table 4: The mean Fo (sp) (Hz) in T.E. speakers by various investigators.

The hypothesis stating that "there is no significant difference in terms of Fo in speech between

1. Normal and T.E. speakers (with D.B. & I.P.) accepted
   Normal and L.P. aided T.E. speaker rejected
2. D.B. aided and L.P. aided T.E. speakers accepted
3. D.B. aided and I.P. aided T.E. speakers accepted
4. L.P. aided and I.P. aided T.E. speakers rejected

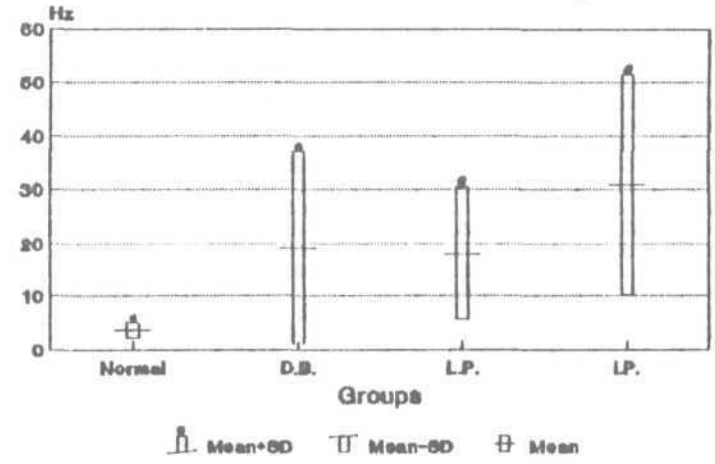
EXTENT OF FLUCTUATION IN Fo (Ex. FF) :

Ex. FF. in phonation of /a/, /i/, and /u/ for normals and T.E. speakers with D.B., L.P. and I.P. prosthesis are presented in Table - 5 and Graph-5,6,and 7.

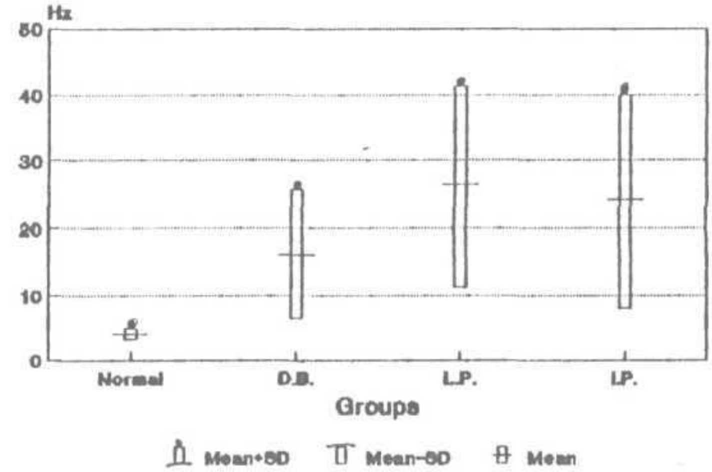
Group		Mean (Hz)	S.D.	Range (Hz)
Normal	/a/	3.56	1.52	1.26 - 5.16
	/i/	4.1	.83	3.11 - 4.97
	/u/	3.96	.71	3.00 - 4.77
D.B.	/a/	19.17	18.06	0.00 - 55.96
	/i/	16.06	9.56	3.66 - 35.66
	/u/	24.09	15.36	3.16 - 50.2
L.P.	/a/	18.06	12.48	3.91 - 42.69
	/i/	26.31	15.31	3.98 - 51.96
	/u/	23.73	10.21	0.00 - 40.62
I.P.	/a/	30.82	20.69	3.34 - 56.81
	/i/	23.96	16.03	3.91 - 42.81
	/u/	27.73	17.23	4.26 - 50.24

Table - 5 :- The Mean S.D. & Range of Ex. F. F. (Hz) in phonatio of /a/, and /u/ for normal D.B., L.P. and I.P. groups.

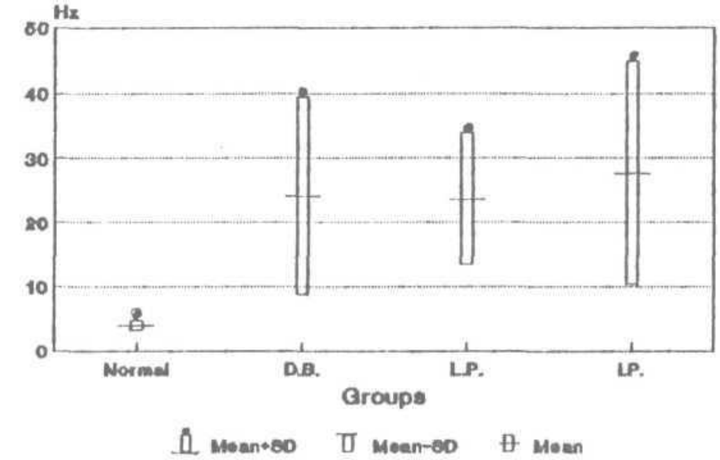
Table - 5 reveals that T.E. Speakers showed greater Ex. F.F. than the normal groups. Among T.E.P. more Ex. F.F. was seen in I.P. aided T.E. speakers than D.B. and L.P. aided amoung T.E. speakers L.P. aided T.E. speakers showed more Ex. F.F. in phonation of / i / with the I.P. aided showing higher values in the phonation of /a/ & /u/.



Graph-5:Ex F.F. OF /a/



Graph-6:Ex.F.F. OF /i/



Graph-7:Ex.F.F. OF /u/

The mean Ex. F.F. in phonation of /a/ for T.E. Speakers of this study were higher as compared to previous studies. (Table - 6)

Investigator	Mean Ex. F. F.(Hz)
Rajashekhar **et.al.(1990)**	9.2 (L.P.)
Rajashekhar (1991)	13.3 (L.P.)
Present study (1993)	19.17 (D.B.)
	18.06 (L.P.)
	30.82 (I.P.)

Table -6:- The Mean Ex. F.F. in T.E. speakers reported by different investigators.

Results of the wilcoxon test for matched pairs are showed in Table-31.Significant difference in normal and T.E.P. group in Ex. F.F. in phonation. With in T.E.P. group no significant difference observed across prosthesis except between D.B. Vs L.P. which was significant only in the phonation of /i/ vowel.

The hypothesis stating that these is no significant difference in terms of Ex. F.F. between

1. Normals and T.E. speakers (with D.B., L.P. & I.P.) rejected
2. D.B. aided and L.P. aided T.E. speakers accepted
3. D.B. aided and I.P. aided T.E. speakers accepted
4. L.P. aided and I.P. aided T.E. speakers accepted

Hence the results of the present study showed that the Ex. F.F. in phonation of all the three vowels were greater in T.E.P. group than in normals, but there was no difference with in different types of prosthesis. This indicated less stability in the control of fundamental frequency in phonation in T.E. speakers.

4. SPEED OF FLUCTUATION IN Fo (Sp. F.F.)

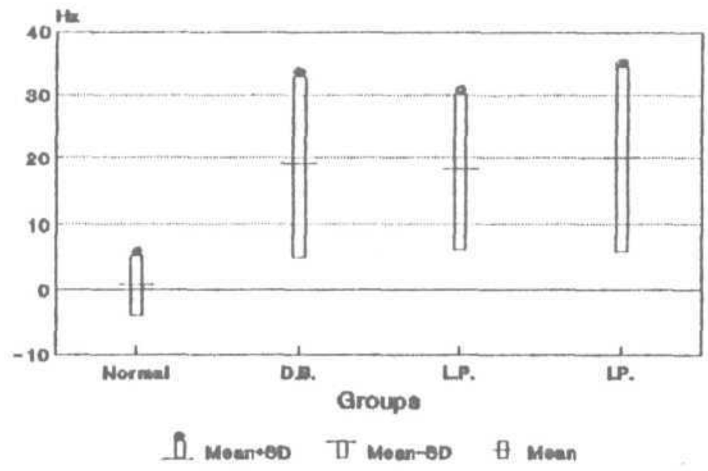
Table 7 and Graphs 8,9, and 10 shows the results with reference to sp. F.F. in phonation of /a/, /i/, and /u/ for the four groups.

Group		Mean	S.D.	Range
Normal	/a/	7	4.61	.49-13.16
	/i/	7.5	3.05	03.91-11.87
	/u/	8.51	3.77	01.91-10.78
D.B.	/a/	19.00	14.05	0.00 -41.67
	/i/	19.48	11.99	1.56-38.23
	/u/	19.08	12.54	.98-40.28
L.P.	/a/	18.23	12.03	2.44-37.78
	/i/	20.65	9.39	5.55-32.39
	/u/	20.72	9.22	0.00-32.38
I.P	/a/ -	20.17	14.28	2.42-41.7
	/i/	19.93	14.21	4.72-40
	/u/	23.0	12.11	4.92-38.88

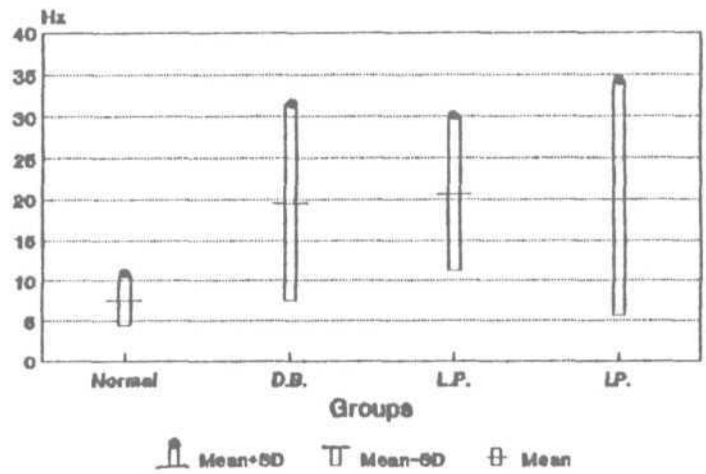
Table 7. The Mean, S.D. and range of Sp. F.F. in phonation of /a/, /i/ and /u/ for normal D.B. L.P. and I.P. groups.

The Sp. F.F. in phonation of T.E. speaker was greater than that of the normal group. With in T.E.P. group L.P. aided T.E. speaker showed greater SP. F.F. than D.B. and I.P. aided L.P. aided T.E. speaker showed more SP F.F. in phonation of /i/ and /u/ as I.P. aided showed more in phonation of /a/

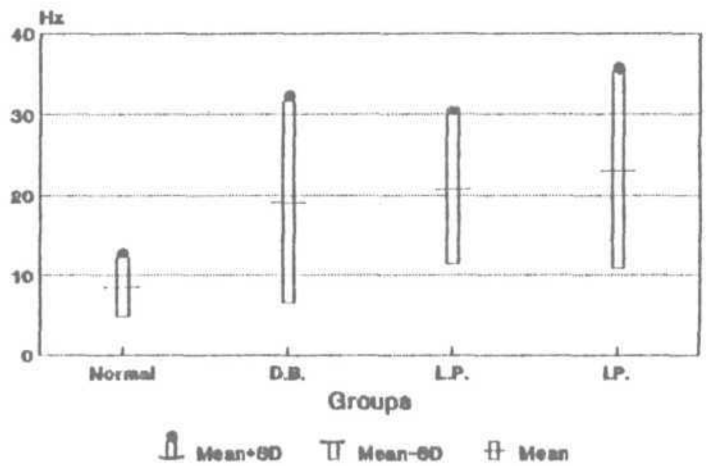
The mean sp. F.F. in phonation of /a/ for T.E. speakers of this study were higher as compared to previous studies (Table - 8)



Graph-8:Sp.F.F. OF /a/



Graph-9:Sp.F.F. OF /i/



Graph-10:Sp.F.F. OF /u/

Investigator	Mean Sp. F.F. (Hz)
Rajashekhar et.al. (1990)	14 (L.P.)
Rajashekhar (1991)	14.6 (L.P.)
present study (1993)	19 (D.B.)
	18.23 (L.P.)
	20.17 (I.P.)

Table -8:- The Mean Sp. F.F. in T.E. speakers reported by differenc investigators

Wilcoxon test concludes that there is significant difference in normal and T.E.P. group in Sp. F.F. in phonation as shown in Table-31. There was no significant difference in T.E. speakers across prosthesis group.

The hupothesis stating that there is no significant difference in terms of Sp. F.F. between

1. Normals and T.E. speakers (with D.B., L.P., & I.P.) rejected
2. D.B. aided and L.P. aided T.E. speakers accept
3. D.B. aided and I.P. aided T.E. speakers accept
4. L.P. aided and I.P. aided T.E. speakers accepted.

Thus the results of the present study showed increased Sp. F.F. in phonation of / a/, /i/ and /u/ for T.E. speakers than normal and there was no difference across different prosthetic conditions. It suggested that availability of pulmonary air supply to the T.E. speakers and type of prosthesis used didnot improve the vibratory patterns at the pseudoglottis.

5. FREQUENCY RANGE IN PHONATION (FR)

Table -9 and Graphs 11,12,and 13 present the FR in phonation of /a/, /i/and /u/ for normal and T.E.P. group with D.B., L.P. and I.P. prosthesis.

Group		Mean (Hz)	SD	Range
Normal	/a/	17.4	22.80	6-58
	/i/	12.6	8.82	6-28
	/u/	9.2	4.76	5-17
D.B.	/a/	65.33	61.98	2-199
	/i/	72.25	47.20	6-147
	/u/	83.13	59.71	6-171
L.P.	/a/	61.2	32.55	11-100
	/i/	81.07	46.93	10-162
	/u/	100.6	48.80	3-176
I.P.	/a/	98.25	76.50	4-254
	/i/	87.83	61.44	17-206
	/u/	94.92	51.89	16-188

Table-9: Mean,S.D.and Range of FR in phonation of /a/,/i/ and /u/ fo normal, D.B., L.P. and I.P. groups.

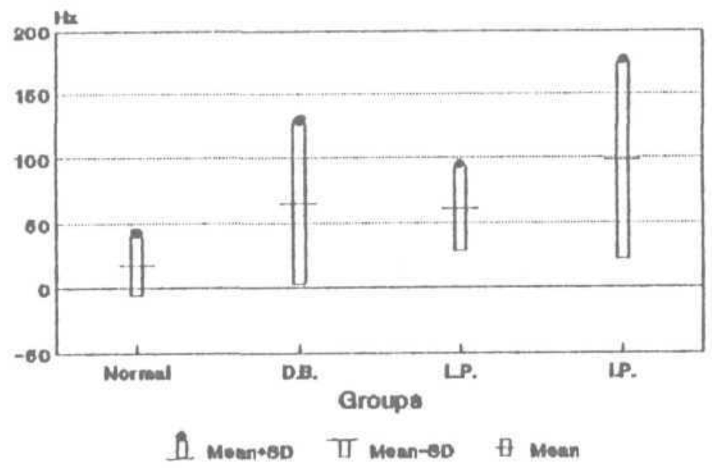
The frequency range of 17.4 Hz in /a/ for the normal group of the present study was higher than that reported by other investigators(Robbins et.al. 1984; Nataraja, 1986)

I.P. aided T.E. speakers showed greater FR in phonation than D.B. and L.P. aided showed more in Table-9. I.P. aided T.E. speakers showed higher FR in phonation of /a/ and /i/, where as L.P. aided showed more in /u/.

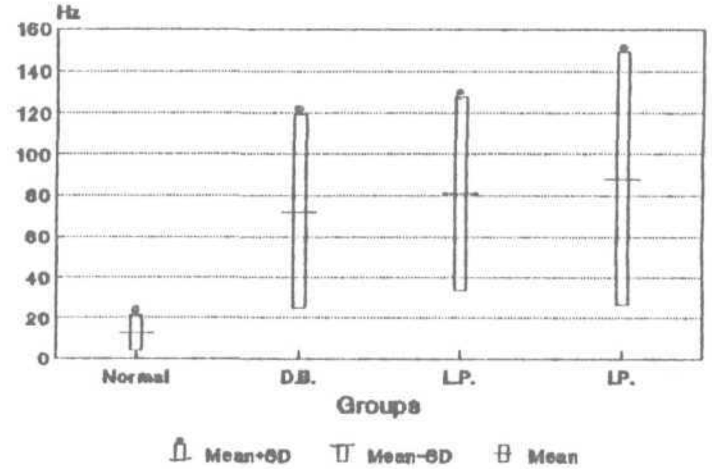
The mean FR in phonation of /a/ for T.E. speakers of this study were higher as compared to previous studies (Table-10).

Investigator	Mean FR (Hz)	
Robbins **et.al.** (1984)	39.9	
Rajashekhar (1991)	45	(L.P.)
Present study (1993)	65.33	(D.B.)
	61.2	(L.P.)
	98.25	(I.P.)

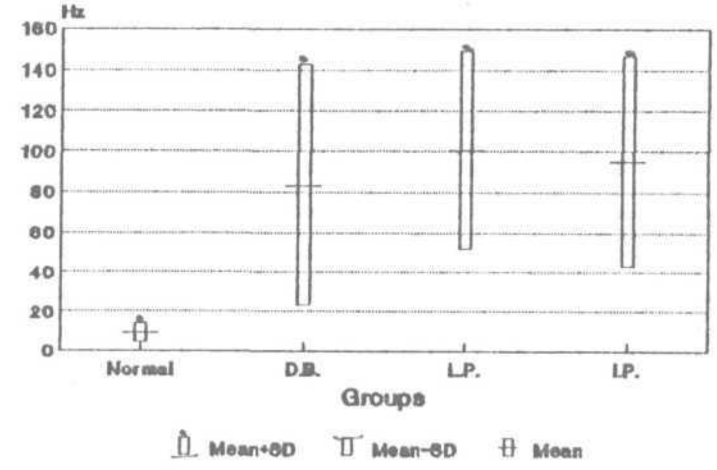
Table-10 :- The Mean FR in T.E. speakers reported by different investigators.



Graph-11:FR FOR PHONATION OF /a/



Graph-12: FR FOR PHONATION OF /i/



Graph-13: FR FOR PHONATION OF /u/

The variability (SD) in the T.E.P. group of present study were considerably high as compared to reports made by Robbins et.al. (1984) and Rajashekhar (1991).

Results of wilcoxon test for matched pairs (as shown in Table 31) shows that there is significant difference in FR in phonation of normal and T.E.P. groups. There is no significant difference in FR in phonation with in T.E. speakers groups across prosthesis.

The hypothesis stating that `` there is no significant difference in terms of FR in phonation. between

1 Normal and T.E. speakers (with D.B., L.P. & I.P.) rejected

2. D.B. aided and L.P. aided T.E. Speaker accepted

3. D.B. aided and I.P. aided T.E. Speaker accepted

4. L.P. aided and I.P. aided T.E. Speaker accepted

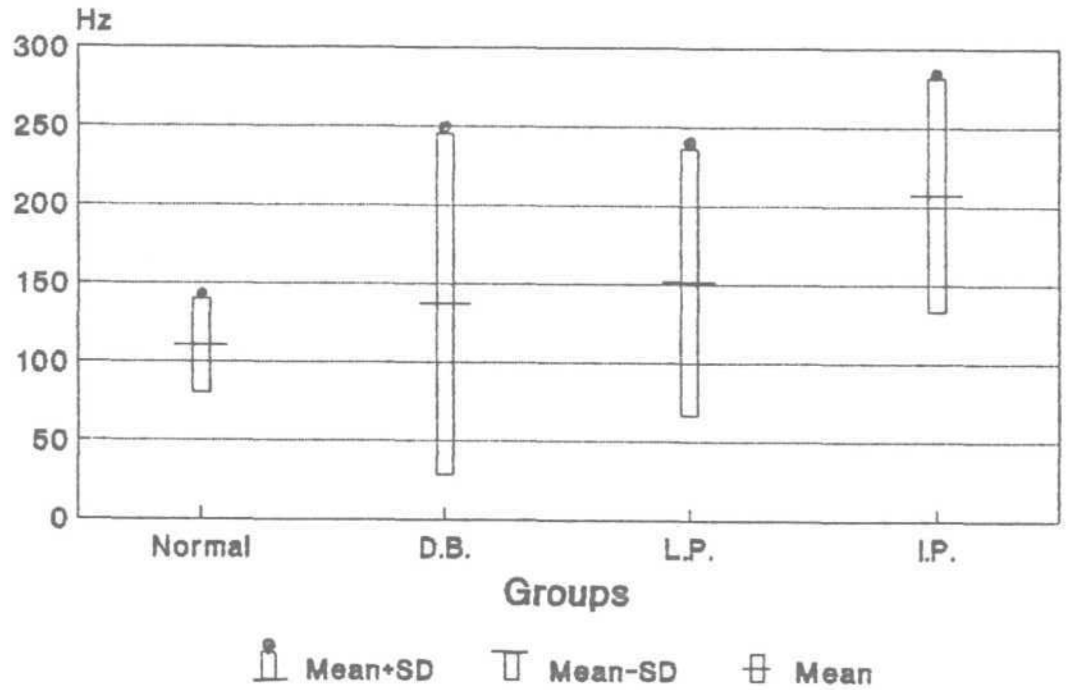
Thus, it was concluded that there was no difference in FR in phonation across prosthesis.

6. FREQUENCY RANGE IN SPEECH [FR(SP)]

FR in speech measure from the analysis of the three sentences (three repetions each) spoken by the normal and T.E. speakers with I.P., D.B. and L.P. type of prosthes is presented in Table 11 and graph 14

Group	Mean	S.D.	Range
Normal	110.4	29.54	78-155
D.B.	137.07	108.62	0-283
L.P.	151.64	84.84	2-265
I.P.	207.25	74.34	74-288

Table -11:- Mean S.D. and Range - of FR in speech for normal D.B., L.P. and I.P.groups.



Graph-14: FR FOR SPEECH

The frequency range in speech for the normal group of this study was similar to findings of Hudson & Halbrook (1981). The mean FR in speech for T.E. speakers of this study and other studies are shown in Table 12.

Investigator	Mean FR
Robbins et.al. (1984)	142
Pindzola & Cain (1989)	170
Rajashekhar (1991)	111.4 (L.P.)
present study (1993)	137.07 (D.B.)
	151.64 (L.P.)
	207.25 (I.P.)

Table - 12:- The Mean FR in speech in T.E. speakers reported by different investigators.

In the present study larger FR in speech is seen with I.P. aided T.E. speakers as compared to D.B. and L.P. aided speakers. The wilcoxon test results shows that (Table 31) there is no significant difference between normal and L.P. and D.B. aided T.E. speakers groups were found, but there was significant difference between normal and I.P. aided T.E. speaker group. With in T.E. speaker group there was significant difference between L.P. aided and 1.P. aided T.E. speaker and D.B. aided and I.P. aided T.E. speakers but no significant difference between D.B. aided and L.P. aided T.E. speakers group.

The hypothesis stating that `` these is no significant difference in terms of FR in speech between

1. Normal and D.B. and L.P. aided T.E. speaker accepted
2. Normal and I.P. aided T.E. speaker rejected
3. D.B. aided and L.P. aided T.E. speaker accepted
4. D.B. aided and I.P. aided T.E. speaker rejected
5. L.P. aided and I.P. aided T.E. speaker rejected.

This suggests that I.P. aided T.E. speaker differ from normal D.B. and L.P. aided T.E. speakers, but no difference was seen with in D.B. and L.P. aided T.E. speakers.

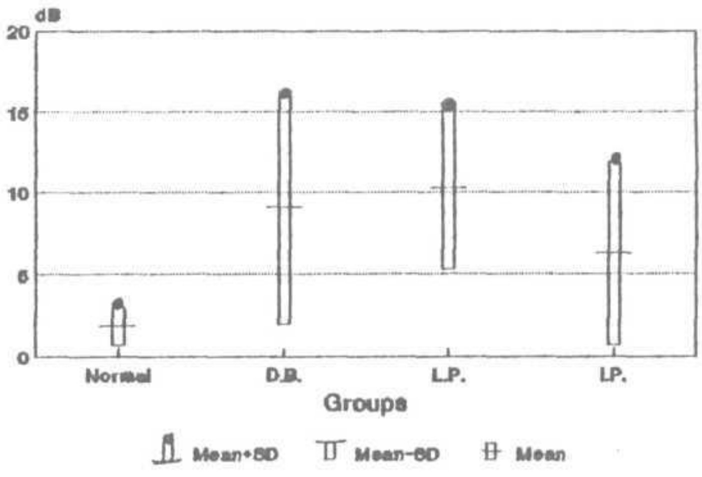
7. EXTENT OF FLUCTUATION IN INTENSITY (Ex.F.I)

Ex. F.I. in phonation of /a/, /i/ and /u/ for normal and T.E speakers with D.B. L.P. and I.P prosthesis are presented in Table 13 and Graphs 15,16, and 17.

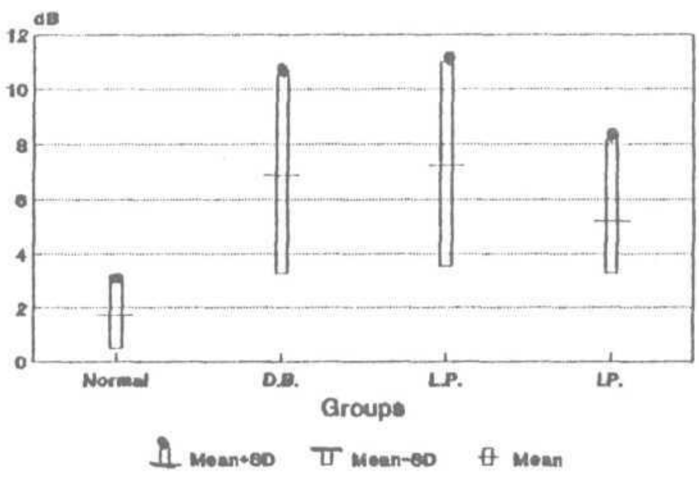
Group		Mean (dB)	S.D.	Range (dB)
Normal	/a/	1.88	1.88	1.01-3.21
	/i/	1.73	1.23	0-3.13
	/u/	1.02	1.02	0-2.07
D.B.	/a/	9.05	7.02	3.64-24.75
	/i/	6.89	3.61	3.82-12.22
	/u/	7.48	0.34	0-23.27
L.P.	/a/	10.26	4.90	3.55-19.60
	/i/	7.25	3.71	0-13.31
	/u/	7.86	4.30	3.27-15.97
I.P.	/a/	6.28	5.56	0-22.80
	/i/	5.21	2.95	3.12-14.40
	/u/	4.73	0.74	3.60-05.88

Table - 13:- The Mean, S.D. and Range of Ex. F.I. in phonation of /a/, /i/ and /u/ for normal D.B., L.P. and I.P. groups.

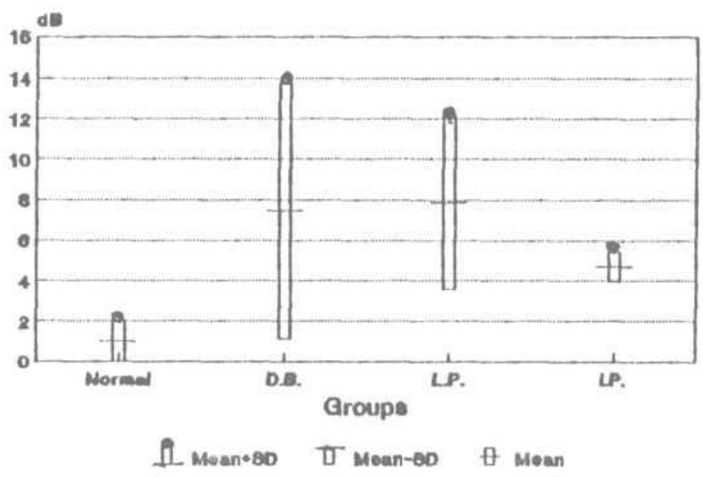
Inspection of Table - 13 revealed that the means of Ex. F.I. were more in T.E.P. group phonation than in normals. Further among the T.E.P. groups the highest Ex. F.I. was seen in L.P. aided T.E. speakers and least in I.P. aided T.E. speakers for all the vowels.The mean Ex. F.I. in phonation was considerably high in the present study as compared to Rajashekhar's 1991 study



Graph-15:Ex.F.I. OF /a/



Graph-16: Ex.F.I. OF /i/



Graph-17: Ex.F.I. OF /u/

Table -31 presents result of wilcoxon test for the four groups. Comparison of group means showed that the T.E.P. group significantly differed from the normal group for Ex. F.I. where as among T.E.P. groups no significant differces were found across prosthetic conditions.

The higher Ex. F.I. for T.E.P. groups reflected inability to maintain the intensity of voice.

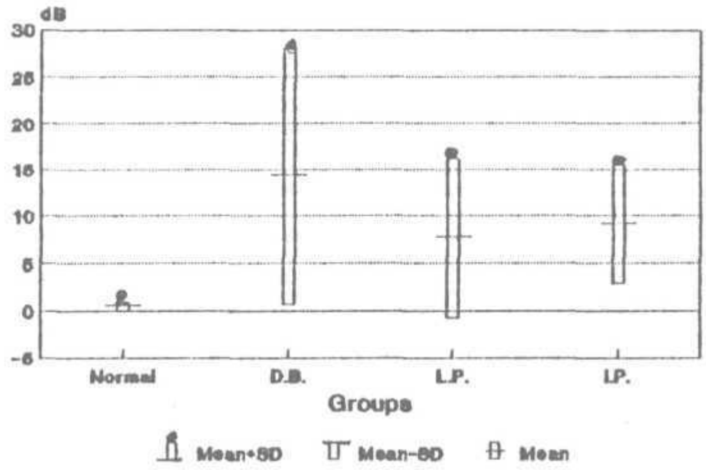
The hypothesis stating that `` there is no significant difference in terms of Ex. F.I. between

1. Normals and T.E. speakers (with D.B.,I.P. & L.P.) rejected
2. D.B. aided and L.P. aided T.E. Speakers accepted
3. D.B. aided and I.P. aided T.E. Speakers accepted
4. L.P. aided and I.P. aided T.E. Speakers accepted

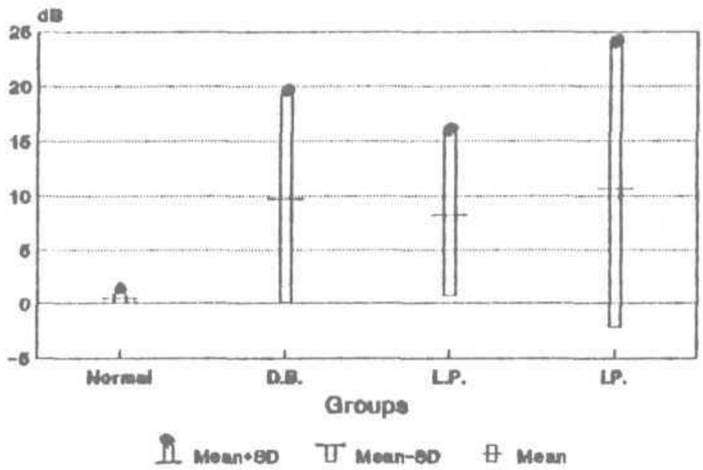
8. SPEED OF FLUCTUATION IN INTENSITY (Sp.F.I.)

The results obtained for the following four groups with respect to this parameter are provided in Table-14 and Graph-18,19,and 20. The sp. F.I. in phonation of T.E. speaker was greater than that of the normal group. Among T.E. speakers I.P. aided T.E. speakers showed more Sp. F.I. than D.B. and L.P. aides T.E. spekaers in the phonation of /i/ and /u/ vowels only, the D.B. aides T.E. speakers showed more sp. F.I. in phonation of /a/ vowel than L.P. and I.P aides T.E. speakers.

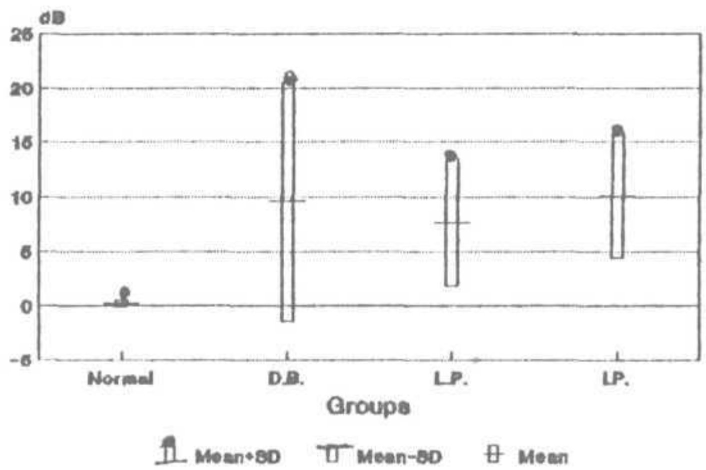
The mean Sp. F.I. in phonation was high as compared to previous study done by Rajashekhar (1991)



Graph-18: Sp. F.I. of /a/



Graph-19: Sp.F.I. of /i/



Graph-20: Sp.F.I. of /u/

		Mean	S.D.	Range
Normal	/a/	0.50	0.40	.17 -1.19
	/i/	0.47	0.52	0 -1.29
	/u/	0.27	0.33	0 -0.80
D.B.	/a/	14.37	13.63	.92
	/i/	9.67	9.50	2.36-35.29
	/u/	9.57	11.01	0-33.33
L.P.	/a/	7.78	8.46	1.67-30.55
	/i/	8.23	7.54	0-23.94
	/u/	7.64	5.76	1.89-22.73
I.P.	/a/	9.19	6.24	0-21.43
	/i/	10.66	12.89	1.66-50
	/u/	10.09	5.67	3.80-21.15

Table-14 : The Mean, S.D., and Range of Sp. F.I. in phonation of /a/, /i/ and /u/ for normal D.B., L.P. and I.P. groups .

The Wilcoxon test indicated significant difference in the Sp. F.I. in normal and T.E.P. groups (with D.B., L.P. & I.P.prosthesis). However there were no significant differences across the prosthetic conditions (Table - 31). This suggested that type of prosthesis used did not improve the vibratory patterns at the pseudoglottis.

The hypothesis stating that there is no significant difference in terms of Sp. F.I. between

1. Normals and T.E.P. group (with D.B., L.P. & I.P.) rejected.
2. D.B. aided and L.P. aided T.E. speakers accepted
3. D.B. aided and I.P. aided T.E. speakers accepted
4. L.P. aided and I.P. aided T.E. speakers accepted

9.INTENSITY RANGE IN PHONATION (IR)

In the present study, the IR in the phonation of /a/, /i/ and /u/ was greater in the T.E.P. groups when compared to the normal group (Table - 15 and Graphs 21, 22, and 23).

Group		Mean (dB)	S.D.	Range
Normal	/a/	5.6	2.88	2-8
	/i/	5.2	2.17	2-8
	/u/	4.0	2.00	1-6
D.B.	/a/	30.6	14.99	6-49
	/i/	31.75	12.60	14-52
	/u/	27.80	17.18	2-49
L.P.	/a/	42.6	14.15	15-59
	/i/	35.93	17.31	4-58
	/u/	35.87	17.19	7-56
I.P.	/a/	25.83	12.04	4-47
	/i/	22.08	10.53	6-50
	/u/	20.00	7.87	0-31

Table - 15 : The mean S.D. and Range of IR in phonation of /a/, /i/ and /u/ for normal D.B., L.P. and I.P. groups.

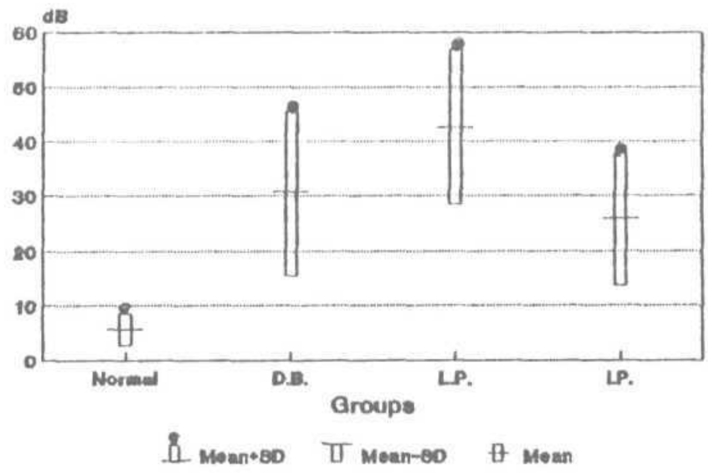
The intensity range for normals in phonation of /a/ obtained in this study agreed with the reports of Nataraja (1986) and vanaja (1986) L.P. aided T.E. speakers had greater IR than D.B. and I.P.aided for all the vowels.

The mean IR in phonation of /a/ for T.E. speakers of this study and other studies are shown in Table-16.

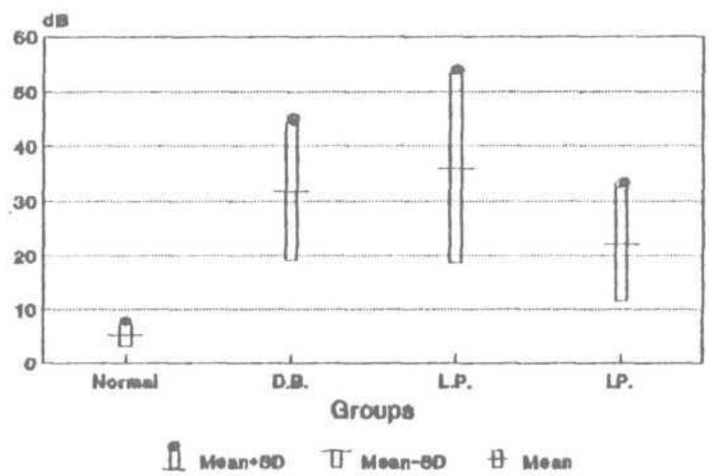
Investigators	Mean IR (dB)	
Singer (1983)	20-29	
Robbins et.al. (1984)	13-8	
Rajashekhar (1991)	13.6	(L.P.)
present study (1993>	30.6	(D.B.)
	42.6	(L.P.)
	25.83	(I.P.)

Table-16 : The mean IR (dB) in T.E. speakers reported by different investigators.

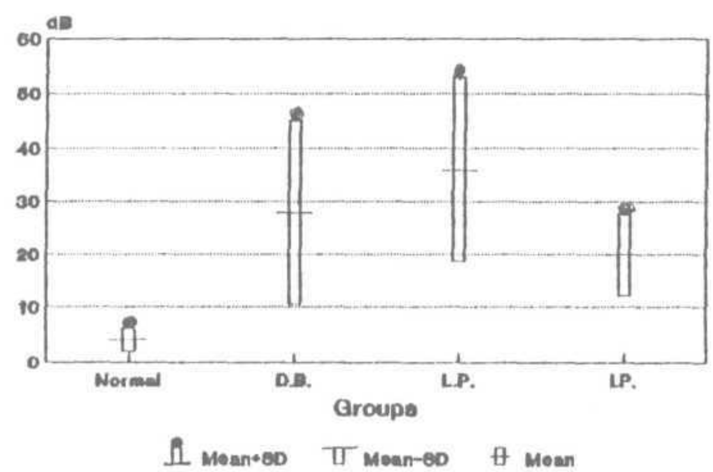
However a significant difference was seen on Wilcoxon test between normal and T.E.P. groups. Among T.E.P. groups significant



Graph-21: IR in Phonation of /a/



Graph-22: IR in Phonation of /i/



Graph-23: IR in Phonation of /u/

differences were seen between

1. D.B. aided T.E. speakers and L.P. aided T.E. speakers in phonation of /a/ and /i/ only

2. D.B. aided and I.P. aided T.E. speakers in phonation of /i/ and /u/ only.

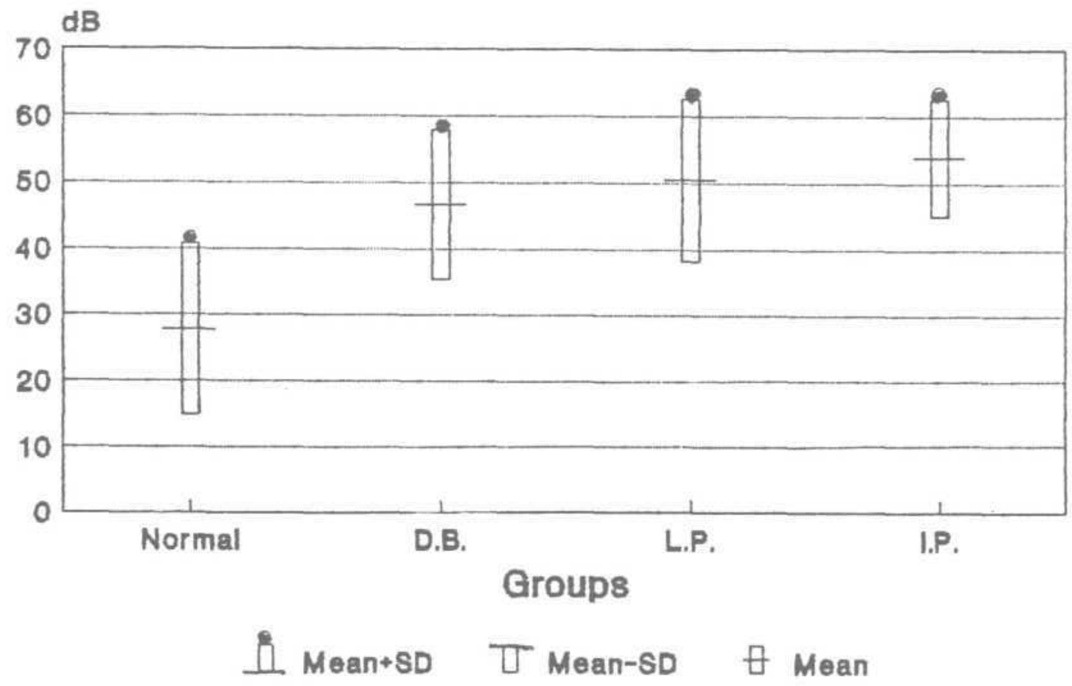
3. L.P. aided and I.P. aided T.E. speakers in phonation of /a/ and /u/ only. Therefore, significant differences were observed across all the prosthesis groups, L.P. aided T.E. speakers showing highest IR and I.P. aided showing the lowest IR. It suggests that none of the T.E. speaker could maintain the intesity at a steady level as compared to normal.

The hypothesis stating that there is no significant difference in terms of IR in phonation between

1. Normal and T.E. speakers (with D.B. I.P. & L.P.) rejected
2. D.B. aided and L.P. aided T.E. speaker rejected
3. D.B. aided and I.P. aided T.E. speaker rejected
4. L.P. aided and I.P. aided T.E. speaker rejected

10.INTENSITY RANGE IN SPEECH [IR (Sp)]

The intensity range in speech obtained for the normal group jn the present study was in agreement with Nataraja's report (1986). Among T.E.P. group L.P. aided T.E. speaker showed highest IR and D.B. aided showed lowest IR in speech (Table-17 and Graph -24)



Graph - 24 : IR in Speech

Group	Mean (dB)	SD	Range
Normal	27.8	12.85	19-49
D.B.	46.73	11.26	23-63
L.P.	50.40	12.17	23-62
I.P.	53.83	8.8	34-63

Table 17 : The Mean, S.D., and Range of IR (dB) in speech for normal D.B., L.P. and I.P. groups.

The IR in T.E. speakers (with D.B., I.P. and L.P. prosthesis) was reported to be higher than reported by other investigators (Singer, 1983; Robbins et.al., 1984, Rajashekhar, 1991). Statistical analysis (Table-31) indicated significant difference among normal and T.E.P. groups but no significant differences were noticed among T.E. speakers across prosthesis.

The hypothesis stating that `` there is no significant difference in terms of IR in speech between

1. Normal and T.E.P. groups rejected
2. D.B. aided and L.P. aided T.E. speaker accepted
3. D.B. aided and I.P. aided T.E. speaker accepted
4. L.P. aided and I.P aided T.E. speaker accepted

Results indicated that the type of prothesis used had no effect on the IR in speech in T.E. speaker.

11.MAXIMUM PHONATION DURATION (MPD)

The MPD varied among groups. T.E. speakers showed lower MPD than normals(Table -18 and Graph-25,26,and 27). It was evident from the table that the MPD for all the three groups was maximum during phonation of /a/ and minimum during phonation of /u/. The mean MPD in normal speakers of this study was lower than the normative data reported for adult males by investigators in Indian population (Sheela, 1974; Jayaram,1975; Vanaja, 1986; Nataraja,1986). The mean MPD for

Group		Mean (Sec)	SD	Range
Normal	/a/	12.33	4.63	8.20-17.63
	/i/	11.06	3.47	6.98-15.07
	/u/	11.06	3.42	7.66-16.14
D.B.	/a/	5.25	4.27	1.00-15
	/i/	4.22	4.88	0.50-18.70
	/u/	3.60	3.26	1-10.50
L.P.	/a/	6.43	6.23	1.3-24.20
	/i/	4.08	2.83	1.3-10
	/u/	4.75	4.94	1-16.5
I.P.	/a/	2.07	1.26	.9-4.4
.49	/i/	1.55		.9-2.5
	/u/	1.24	.27	.9-1.6

Table-18 : The Mean, S.D., and Range of MPD in phonation of /a/, /i/ and /u/ (sec) for normal,D.B., L.P. and I.P. groups.

/a/ in T.E.P. group of this study was less than the values reported by Robbins et.al.(1984), Pindzola and Cain (1989), Omari et.al. (1989), Rajashekhar(1991). Among T.E. speakers of this study the higher MPD was seen in L.P. aides T.E. spekers and lower in I.P. aided.

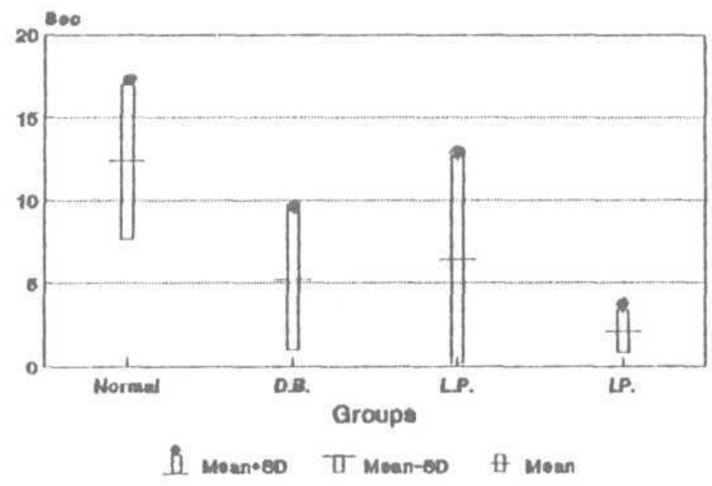
As a group, the T.E. speakers in the present study presented lower MPD values than the normal laryngeal speakers inspite of the use of pulmonary air. Robbins et.al.(1984) attributed the low MPD values in T.E. speakers as compared to normals to the high trans-source flow rates and poor digital occlusion of stoma resulting in leakage of pulmonary air prior to its diversion into the Oesophagus by the prosthesis. Pindzok and Cain(1989) considered the resistance offered by the prosthesis to partly explain the reduced MPD in the T.E.P. group. These explanations can be accounted for the lesser than normal MPD values in the T.E. speakers in the present study.

The statistical analysis shows that (Table-31) there is a significant difference between normals and T.E. speakers. Among T.E. speakers there were significant differences between 1. D.B. aided and I.P. aided T.E. speakers 2. L.P. aided and I.P. aided T.E. speakers but no significant difference was found between D.B. aided and L.P. aided T.E. speakers.

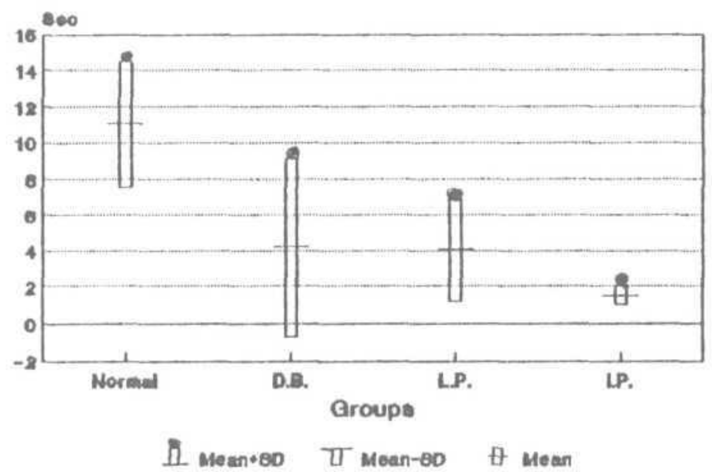
The hypothesis stating that ^ there is no significant difference in terms of MPD between

1. Normal and T.E. spekaers	rejected
2. D.B. aided and I.P. aided T.E. speakers	rejected
3. L.P. aided and I.P aided T.E. speakers are	rejected.
4. D.B. aided and L.P. aided T.E. speakers	accepted.

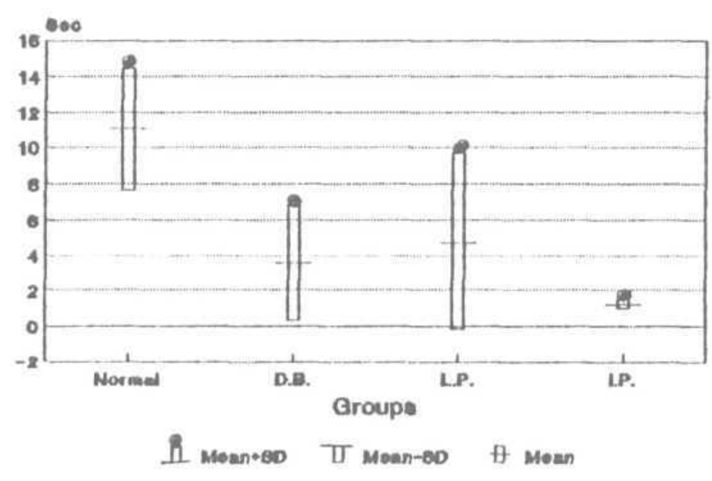
Thus it was observed that among T.E. speakers both L.P. and D.B. aided T.E. speakers had higher MPD than I.P. aided T.E. speakers.



Graph-25: MPD of /a/



Graph-26: MPD of /i/



Graph-27: MPD of /u/

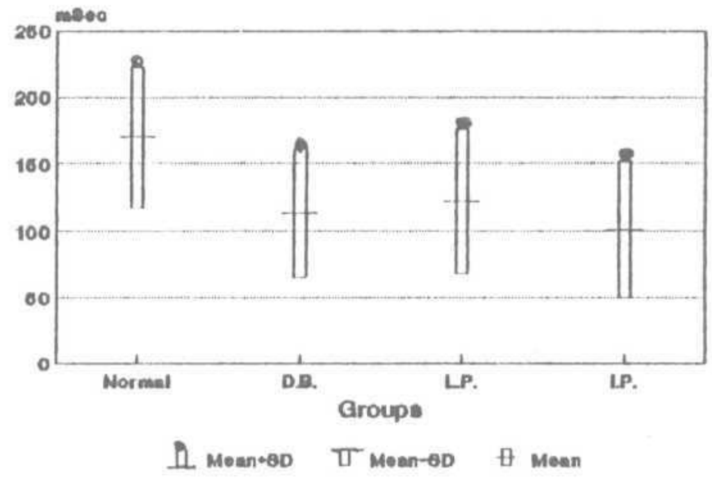
12. RISING TIME IN PHONATION (RT)

Group		Mean(msec)	S.D.	Range
Normal	/a/	170	52.44	80-120
	/i/	172	39.62	130-230
	/u/	182	24.9	140-200
D.B.	/a/	113	47.8	60-200
	/i/	123.64	51.82	80-260
	/u/	112.86	75.08	60-340
L.P	/a/	122.14	54.23	60-200
	/i/	111.33	73.96	60-300
	/u/	82.14	22.59	40-120
I.P	/a/	100.83	51.25	30-200
	/i/	107.5	36.96	60-180
	/u/	110	41.56	60-180

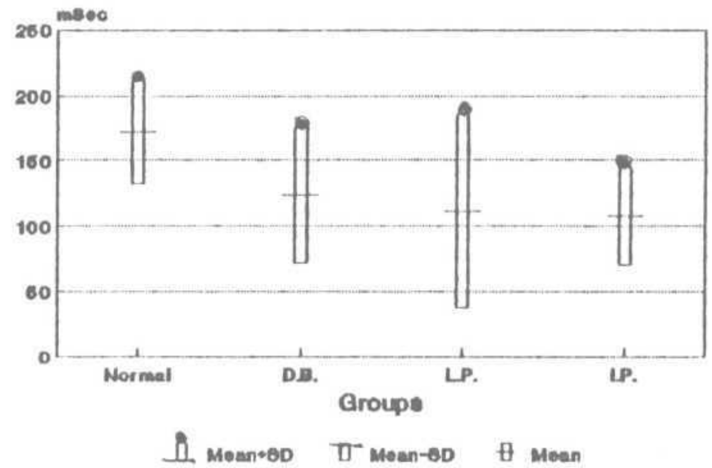
Table-19: The Mean, S.D,and Range of RT (msec) in phonation of /a/,/i/ and /u/ for normal, D.B, L.P and I.P groups.

The RT in phonation for T.E. speakers was shorter than normal speakers (Table-19 and Graph-28,29,and 30) . D.B. aided T.E. speakers showed greater RT in phonation of /i/ and /u/ vowels where as L.P. aided speakers showed greater RT in phonation of /a/ than others.

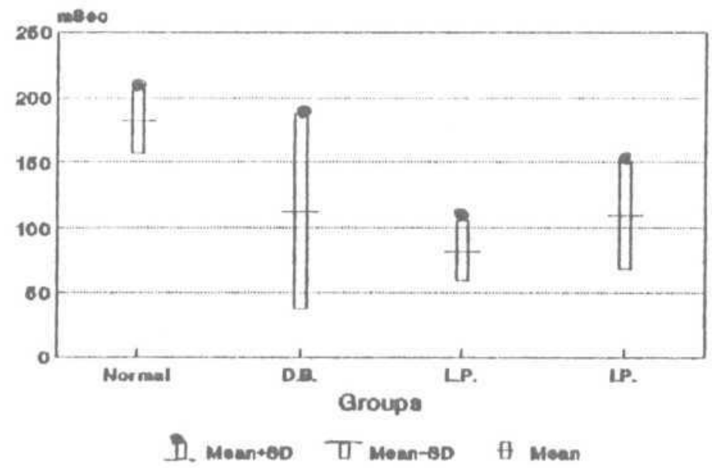
The RT obtained in this study for the normal group was higher than those reported by others (Kim et.al.,1982, Yoon et.al.,198-, Vanaja, 1986; Nataraja, 1986). The RT measures for TE speakers in present study was lower as compared to previous study done by Rajashekhar (1991). In the present study higher RT values was seen in D.B. aided T.E. speakers for the phonation of /a/, /i/ and /u/ than L.P. and I.P. aided. This higher RT values in D.B. could be attributed to higher pressure that builds up to initiate and sustain phonation. D.B. prosthesis is reported to be offering more resistance to air flow than the low pressure prosthesis (Weinberg and Moon, 1982) This shows that even IP



Graph-28: RT in Phonation of /a/



Graph-29: RT in Phonation of /i/



Graph-30: RT in Phonation of /u/

offers less resistance to air flow as like L.P. prosthesis . However, statistically there was no significant difference in T.E. speakers across prosthetic conditions (Table-31). Thus, it can be concluded that the T.E. speakers differ significantly from normals, but among TE speakers type of prosthesis used had no effect on the RT in phonation.

Therefore, the hypothesis stating that there is no significant difference in terms of RT in phonation between

1. Normal and T.E. speakers (with D.B.,I.P.& L.P.) rejected
2. D.B. aided and L.P. aided T.E. speakers accepted
3. D.B. aided and I.P. aided T.E. speakers accepted
4. L.P. aided and I.P. aided T.E. speakers accepted.

13. FALLING TIME IN PHONATION (FT)

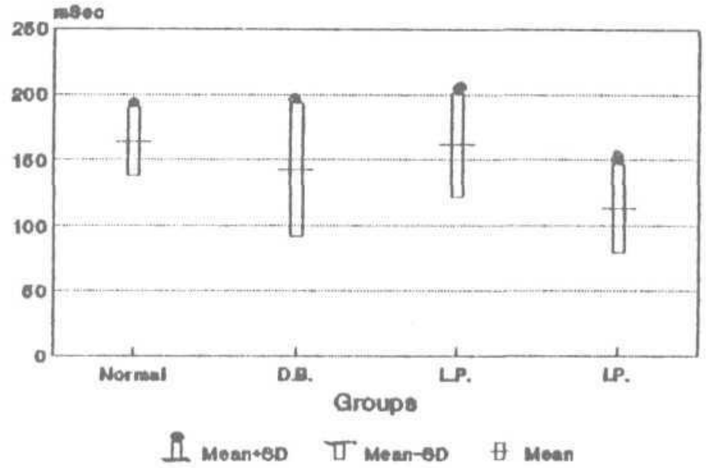
Group		Mean (msec)	S.D.	Range
Normal	/a/	164	26.08	140-200
	/i/	132	37.01	80-170
	/u/	112	32.71	70-150
D.B.	/a/	142.86	50.9	60-240
	/i/	140	33.03	100-200
	/u/	128.33	30.99	80-180
L.P	/a/	161.67	39.73	120-250
	/i/	133.33	40.64	70-220
	/u/	158.67	47.64	100-230
I.P.	/a/	113.33	33.66	80-200
	/i/	144.17	32.89	80-200
	/u/	148.33	36.64	100-200

Table-20: The Mean, S.D. and Range of FT (msec) in phonation of /a/, /i/ and /u/ for normal, D.B., L.P and I.P. groups.

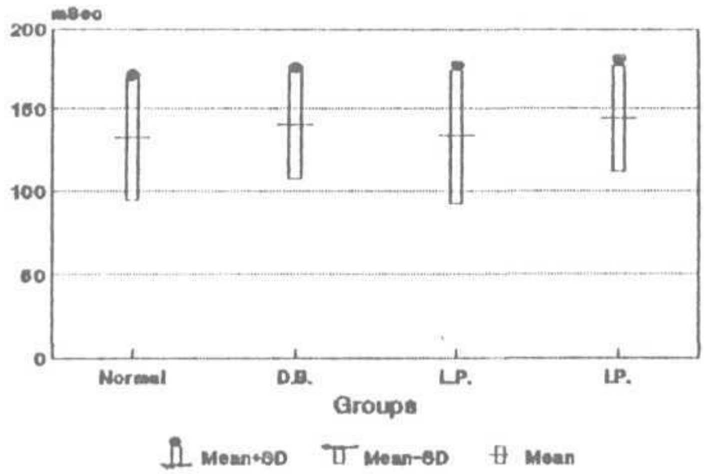
It was interesting to note from Table-20 and Graphs- 31, 32, and 33 that T.E. speakers showed longer FT than normal speakers in /i/ and /u/, where as normals showed longer FT in /a/.

The FT in phonation of /a/ for normals as found in the present study was longer than reported by Nataraja (1986), Vanaja (1986). The FT measured in the present study was shorter than Rajashekhar's (1991) study. The L.P. aided T.E speakers showed longer FT in the phonation of /a/ and /u/, where as I.P. aided speakers showed longer FT in phonation of /i/. Greater volume of air enabling sustained phonation probably increases the FT. Wilcoxon test showed that (Table-31) D.B. and L.P. aided T.E. speakers differed significantly only while phonating /u/ and L.P and I.P. aided differed in phonating /a/, where as there was no significant difference in the phonation of other vowels in terms of FT. similarly, normal and L.P aided differed significantly only in phonation of /u/. I.P. aided T.E. speakers differed significantly from normals in phonation of /a/ and /u/ in terms of FT .

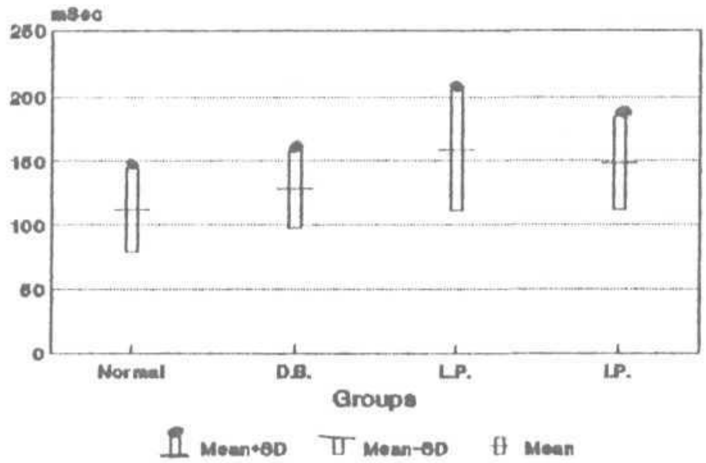
Thus, it was concluded that only I.P. aided T.E. speaker differed significantly from normals where as no significant differences were found between normal and L.P and D.B. aided T.E. speakers. Among T.E. speakers no significant differences found across different prosthetic conditions i.e., type of prosthesis used had no effect on the FT in phonation of T.E. speakers (Note:- out of 3 vowels, if 2 showed significant difference then only it was considered as significant difference across that condition) Thus, the results with reference to FT have been inconsistent, i.e., significant differences were found only on certain vowels and not on others.



Graph-31: FT in Phonation of /a/



Graph-32: FT in Phonation of /i/



Graph-33: FT in Phonation of /u/

The hypothesis stating that "there is no significant difference in terms of FT in phonation between

1. Normal and I.P. aided T.E. speaker rejected,
2. Normal and T.E. speakers (with L.P. and D.B.), accepted
3. D.B. aided and L.P. aided T.E. speakers accepted
4. D.B. aided and I.P. aided T.E. speakers accepted
5. L.P. aided and I.P. aided T.E. speakers accepted.

14. VOWEL DURATION (VD) :-

The mean VD S.D. and Range for normal and T.E. speakers with D.B. L.P. and I. P. prosthesis are presented in Table-21 and Graph 34

Vowel	Normal		D.B.		L.P.		I.P.	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
/a:/	188 (31.4)	153-233	174 (18.36)	154-202	184 (26.37)	155-209	164 (28.57)	122-186
/i/	177 (39.13)	140-223	181 (38.2)	141-241	219 (52.39)	156-285	232 (66.13)	156-316
/u/	191 (29.17)	150-220	175 (34.67)	130-214	179 (60.97)	115-256	195 (40.81)	150-229
/o:/	138 (43.39)	76-193	168 (35.4)	134-208	171 (39.86)	121-221	175 (28.75)	144-210
/e/	80 (18.22)	62-110	74 (15.34)	53-96	84 (12.55)	68-99	69 (11.6)	54-80

Table-21: The Mean, S.D. (parentheses) and Range of vowel duration of /a:/, /i/, /u/, /o:/ and /e/ for normal, D.B. L.P. & I.P. Groups.

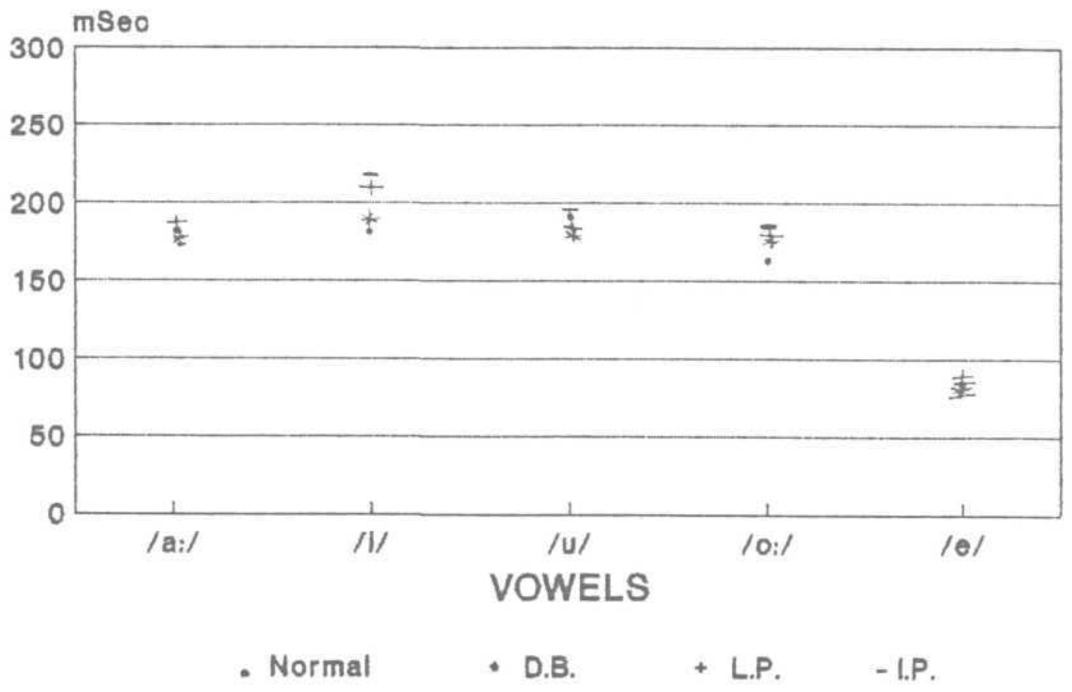
In the present study normals had shorter vowel duration when compared to T.E. speakers. Among T.E. speakers, I.P. aided T.E. speakers had the longest VD in three (/i/, /u/, and /o:/) out of 5 vowels studied. The L.P. aided T.E. speakers had longer VD for the /a:/ and /e/ vowels. As a whole, the T.E. speakers demonstrated longer VD than normal speakers for all the vowels studied. This finding is similar to the results reported by Robbins et. al. (1986) who found longer VD in /i/, /a/ and /u/ vowels in D.B. aided T.E. speakers. Rajashekhar (1991) has reported longer VD in /u/, /i/ and /e/ in L.P. aided T.E. speakers.

Results of the present study support the findings of Robbins et al. (19U6) and Kajashekhar (1991), i.e., normal speakers did not differ significantly from T.E. speakers. Among T.E.P. groups, no significant differences were found across prosthetic conditions except in D.B. and L.P. aided T.E. speakers differed significantly in VD of /i/ vowel.

The increased VD in T.E. speakers can be partly related to the 'non-adductor/adductor' nature of the P.E. segment, as suggested by Doyle, Danhauer and Reed (1988). The explanation offered by Robbins et.al (1986) for longer VD in T.E. speakers is that it may be due to the resistances offered by the prosthesis, but in their study they used D.B. prosthesis. In the present study longer VD was noticed in I.P. aided (for 3 vowels) and L.P. aided (for 2 vowels) T.E. speakers.

VD is also considered to be contributing to the intelligibility of speech. To improve the intelligibility of speech, it is often suggested clinically, to prolong the vowels.

In the present study it was found that the intelligibility was higher for L.P. aided T.E. speakers (83.79%) and I.P. aided T.E. speakers (80.1%) than D.B. aided (76.33%). That means to



Graph-34:MEAN VD in NOR and TEP Groups

say that increased vowel duration in T.E. speaker might have contributed to the intelligibility of speech.

Thus the hypothesis stating that there is no significant difference interms of VD in between

1. Normal and T.E. speakers (with D.B. I.P. & L.P.) accepted
2. D.B. aided and L.P. aided T.E. speakers (except in the VD of /i/) accepted
3. D.B. aided and I.P. aided T.E. speakers accepted
4. L.P. aided and I.P. aided T.E. speakers accepted.
5. D.B. aided and L.P. aided T.E. speaker (in the VD of /i/) rejected

15. VOICE ONSET TIME (VOT) :-

VOT	Normal		D.B		L.P		I.P.	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
/p/	12.2 (4.76)	8-20	32.4 (13.99)	22-56	47.15 (17.52)	18-62	31.52 (7.26)	22-37
/t/	16 (8.15)	6-24	27.34 (15.35)	15-54	24.35 (8.78)	16-39	31.46 (11.45)	14-39
/k/	28.6 (12.56)	11-40	24.73 (6.55)	15-33	36.33 (20.03)	17-69	32.12 (10.98)	18-42

Table-2 The Mean, S.D. (in parentheses) and Range of VOT (msec) of /p/, /t/ and /k/ for normal and T.E. speakes with DB, LP, and I. groups.

The mean VOT (as shown in Table-22 and Graph 35) for /p/, /t/ and /k/ (unaspirated voiceless stops) in the normal group corresponded with the values reported in kannada (Basu, 1979, Sridevi, 1990). T.E. speakers demonstrated greater mean VOT values than normals which was in contrast to the reports by other investigators Robbins et. al., (1986), Klor and Milanti (1980), but was similar to Rajashekhar's (1991) study. Among T.E.P

F2

Vowels	Normal Mean	Normal Range	D.B Mean	D.B Range	L.P Mean	L.P Range	I.P. Mean	I.P. Range
/a:/	1323.6 (50.07)	1286-1411	1223.5 (80.75)	1098-1317.6	1236.08 (118.66)	1098-1411.8	1262.75 (184.07)	1098.01 1521.6
/i/	2039 (124.32)	1945-2196	2460 (324)	2039-2714	2504 (270)	2071-2761	2518 (185)	2274-2714
/u/	960 (60.35)	909-1033	827 (82.41)	753-941	847 (76.86)	784-941	843.12 (75.1)	784.3 941.2
/o:/	981.4 (106.49)	909-1141	938 (113.86)	847-1098	963 (65.08)	863-1020	976 (137.59)	863-1176
/e/	1907 (169.38)	1674-2073	1602 (257.89)	1333-2008	1647 (184)	1490-1882	1663 (179.8)	1412 1835

Table 24 :- Mean S.D. (in parentheses) and Range of F2 (Hz) of /a:/, /i/, /u/, /o:/ and /e/ for normal, DB, LP, and IP groups.

F3

Vowel	Normal Mean	Normal Range	D.B. Mean	D.B. Range	L.P. Mean	L.P. Range	I.P. Mean	I.P. Range
/a:/	2535 (284.87)	2146-2829	2280 (65.27)	2227-2353	2677 (392.22)	2227-2980	2439 (787.5)	1882-2996
/i/	2807 (332.07)	2447-3137	2760.8	-	3529.4	-- --	-	-
/u/	2499 (195.68)	2274-2808	3058	-	-	-	—	—
/o:/	2418.2 (150 98)	2211-2556	2904	-	2305	-	-	-
/e/	2425' (126.57)	2274-2603	2740 (103.1)	2667-2812	2614 (239.41)	2353	2431	-

Tabel 25 :- Mean S.D.(in parentheses) and range of F3(Hz) of /a:/, /i/, /u/, /o:/, and /e/ for normal, D.B., L.P., and I.P. groups.

Table 23,24, and 25 and Graphs 36, 37, and 38 depict the mean formant frequencies (F1,F2, F3) for T.E.P and normal groups. It was found that normals showed higher formant frequencies than T.E.P. for Fl and F2 except Fl in vowels /o:/ and F2 in /i/

say that increased vowel duration in T.E. speaker might have contributed to the intelligibility of speech.

Thus the hypothesis stating that there is no significant difference interms of VD in between

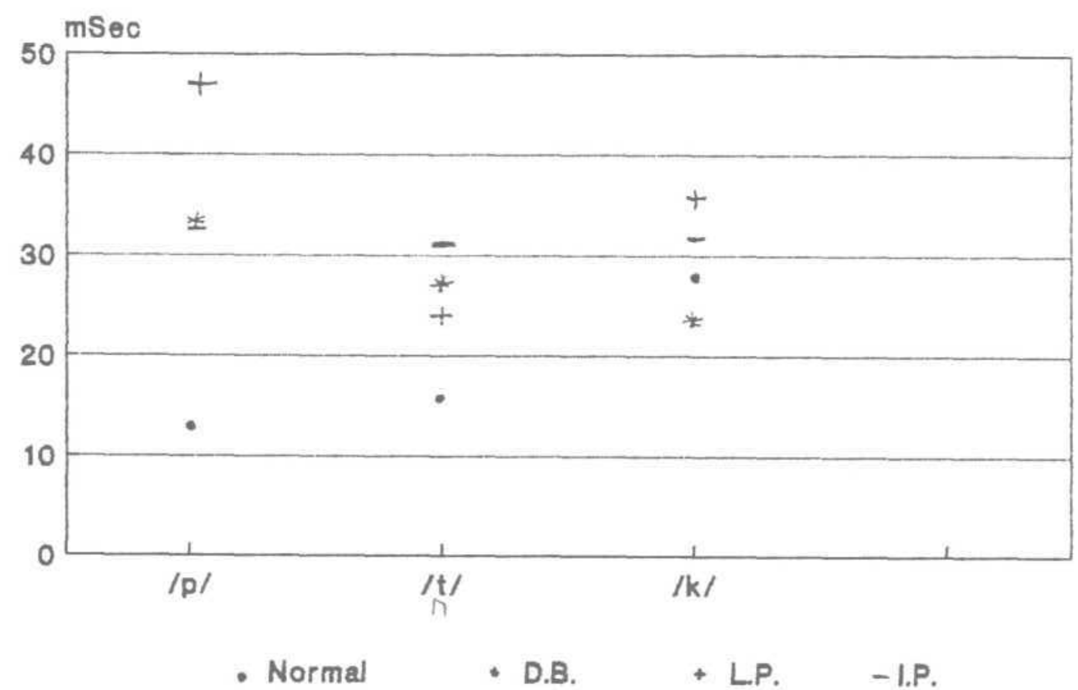
1. Normal and T.E. speakers (with D.B. I.P. & L.P.) accepted
2. D.B. aided and L.P. aided T.E. speakers (except in the VD of /i/) accepted
3. D.B. aided and I.P. aided T.E. speakers accepted
4. L.P. aided and I.P. aided T.E. speakers accepted.
5. D.B. aided and L.P. aided T.E. speaker (in the VD of /i/) rejected

15. VOICE ONSET TIME (VOT) :-

VOT	Normal		D.B		L.P		I.P.	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
/P/	12.2 (4.76)	8-20	32.4 (13.99)	22-56	47.15 (17.52)	18-62	31.52 (7.26)	22-37
/ṭ/	16 (8.15)	6-24	27.34 (15.35)	15-54	24.35 (8.78)	16-39	31.46 (11.45)	14-39
/V	28.6 (12.56)	11-40	24.73 (6.55)	15-33	36.33 (20.03)	17-69	32.12 (10.98)	18-42

Table-2 The Mean, S.D. (in parentheses) and Range of VOT (msec) of /p/, /ṭ/ and /k/ for normal and T.E. speakes with DB, LP, and I. groups.

The mean VOT (as shown in Table-22 and Graph 35) for /p/, /ṭ/ and /k/ (unaspirated voiceless stops) in the normal group corresponded with the values reported in kannada (Basu, 1979, Sridevi, 1990). T.E. speakers demonstrated greater mean VOT values than normals which was in contrast to the reports by other investigators Robbins et. al., (1986), Klor and Milanti (1980), but was similar to Rajashekhar's (1991) study. Among T.E.P



Graph-35: MEAN VOT in NOR and TEP Groups

groups, L.P. aided T.E. speakers demonstrated greater VOT for /p/ and /k/, where as I.P. aided showed greater VOT for /t/.

The explanation offered by Kobbins et. al (1986). can be made applicable to explain for increased VOT in T.E.P. group that is the physical characteristics of the neoglottis exertes a major influence an VOT production in alaryngeal speakers. They further attributed the occurence of different VOT in alaryngeal speakers to aerodynamic capability, myoelastic and motor control properties of the voicing source and consonant-vowel articulatory loci. Rajashekhar (1991) attributed the increased VOT in alaryngeal speakers to the aspiration or murmur associated with the consonant burst. Nearly all the alaryngeal speakers produced aspirated voiceless plosives with murmur (aspiration with voiced) in a few. These two explanations may explain increased VOT in T.E.P group.

Among T.E.P. group, L.P. aided T.E. speakers showed greater VOT but no significant differences were observed across prosthetic conditions ie., type of prosthesis used had no effect on VOT of the T.E. speakers. There was no significant difference between normals and T.E. speakers except for the VOT of /p/ which was significant between D.B. aide T.E. speakers and normaland L.P aided T.E. speakers and normal. (Table-31)

The hypothesis stating that there is no significant difference interims of VOT between

1. Normal and T.E. speakers (D.B., L.P. and I.P) except between D.B. aided and L.P aided T.E. speakers and normals for /p/ which are — rejected. (accepted)

2. D.B. aided and L.P. aided T.E. speakers — accepted

3. D.B. aided and I.P. aided T.E. speakers — accepted

4. L.P. aided and I.P. aided T.E. speakers — accepted.

16. FORMANT FREQUENCIES (Fl, F2, & F3) :-

Difficulties were encountered with respect to the measurement of the formant frequencies in the T.E. speakers because of presence of noise. There was considerable reduction in the intensity of the third formant in most of the T.E. speakers.

Vowels	Normal		D.B.		L.P.		I.P.	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
/a:/	778 (23.84)	737-800	762 (56.13)	706-847	734 (46.25)	690-784	761 (109.8)	706-925
/i/	392 (-)		311 (17.15)	282-329	311 (55.92)	235-392	333 (89.07)	235-423
/u/	462 (69.89)	382-533	404 (23.5)	392-439	384 (52.03)	314-439	427 (41.23)	392-470
/o:/	417 (104.94)	266-517	436 (40.58)	392-471	445 (36.11)	392-471	451 (39.2)	392-471
/e/	521 (123.26)	392-662	467 (55.86)	392-549	471 (55.44)	392-549	482 (84.34)	392-596

Table 23, The Mean, S.D.(in parentheses) and Range of Fl(Hz) of /a:/, /i/, /u/,/o:/ and /e/ for normal D.B., L.P., and I.P. groups.

F2

Vowels	Normal Mean	Normal Range	D.B Mean	D.B Range	L.P Mean	L.P Range	I.P. Mean	I.P. Range
/a:/	1323.6 (50.07)	1286-1411	1223.5 (80.75)	1098-1317.6	1236.08 (118.66)	1098-1411.8	1262.75 (184.07)	1098.01 1521.6
/i/	2039 (124.32)	1945-2196	2460 (324)	2039-2714	2504 (270)	2071-2761	2518 (185)	2274-2714
/u/	960 (60.35)	909-1033	827 (82.41)	753-941	847 (76.86)	784-941	843.12 (75.1)	784.3 941.2
/o:/	981.4 (106.49)	909-1141	938 (113.86)	847-1098	963 (65.08)	863-1020	976 (137.59)	863-1176
/e/	1907 (169.38)	1674-2073	1602 (257.89)	1333-2008	1647 (184)	1490-1882	1663 (179.8)	1412 1835

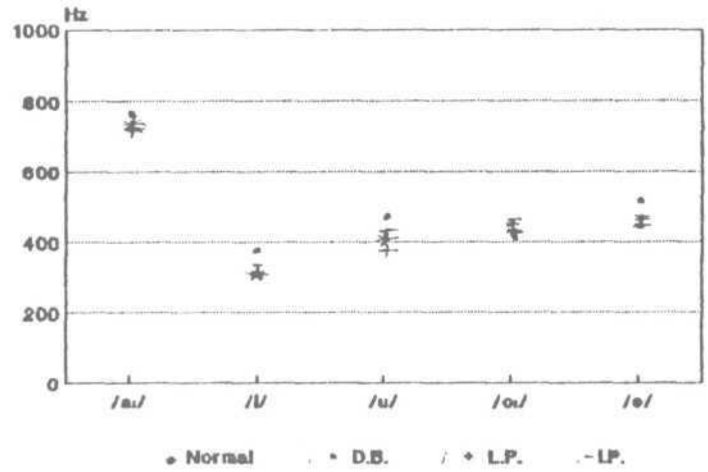
Table 24 :- Mean S.D. (in parentheses) and Range of F2 (Hz) of /a:/, /i/, /u/, /o:/ and /e/ for normal, DB, LP, and IP groups.

F3

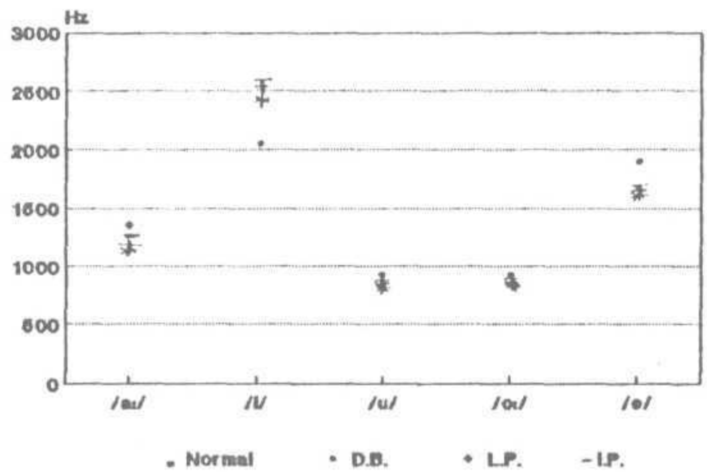
Vowel	Normal Mean	Normal Range	D.B. Mean	D.B. Range	L.P. Mean	L.P. Range	I.P. Mean	I.P. Range
/a:/	2535 (284.87)	2146-2829	2280 (65.27)	2227-2353	2677 (392.22)	2227-2980	2439 (787.5)	1882-2996
/i/	2807 (332.07)	2447-3137	2760.8	-	3529.4	-	-	-
/u/	2499 (195.68)	2274-2808	3058	-	-	-	-	-
/o:/	2418.2 (150)8)	2211-2556	2904	--	2305	-	-	—
/e/	2425 (126.57)	2274-2603	2740 (103.1)	2667-2812	2614 (239.41)	2353 2828	2431	-

Tabel 25 :- Mean S.D.(in parentheses) and range of F3(Hz) of /a:/, /i/, /u/, /o:/, and /e/ for normal, D.B., L.P., and I.P. groups.

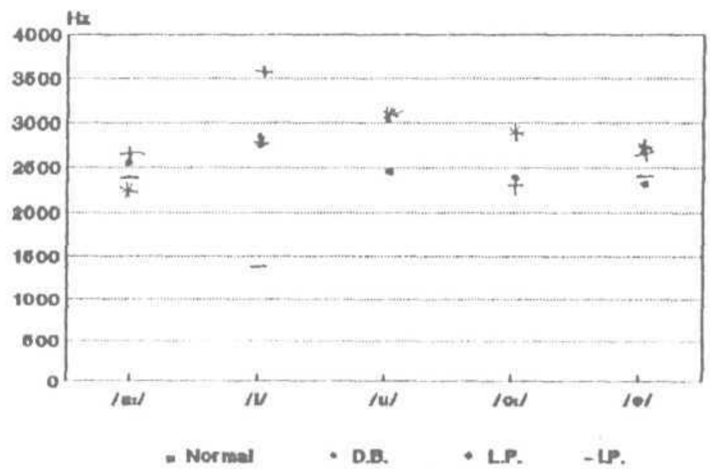
Table 23,24, and 25 and Graphs 36, 37, and 38 depict the mean formant frequencies (F1,F2, F3) for T.E.P and normal groups. It was found that normals showed higher formant freguencies than T.E.P. for Fl and F2 except Fl in vowels /o:/ and F2 in /i/



Graph-36: MEAN F1 in NOR and TEP Groups



Graph-37: MEAN F2 in NOR and TEP Groups



Graph-38: MEAN F3 in NOR and TEP Groups

showed higher value in T.E.P groups. These results were not corresponding with the earlier reports of Weinberg (1982) and Rajashekhar (1991). They had found higher values for formant freguencies (Fl and F2) for T.E.P than normal groups. The values of F3 of the present study confirm their results. Higher values of formant freguencies were noticed in T.E.P. than normal groups. Among T.E.P. groups, I.P. aided T.E. speakers showed higher values for Fl (except in /a:/), and F2 (except in /u/), where as F3 measures were inconsistent.

Wilcoxon test showed that (Table-31) there were no significant differences between normal and groups of T.E. speakers for Fl, F2, F3 for all the vowels except for Fl which was significant between normal and D.B. aided T.E. speakers for /o:/ vowels. No significant differences were observed among T.E. speakers across prosthetic conditions. Thus, it was concluded that there were no significant differences for formant frequencies Fl, F2,and F3 between normal and T.E.P groups and with in T.E.P group across prosthetic groups except for Fl which was significant between normal and D.B. aided T.E. speakers in /o:/ production.

The hypothesis stating that "there is no significant difference in terms of formant frequencies Fl, F2 and F3 for all the vowels between

1. Normal & T.E. speakers (with D.B., L.P. & I.P.) accepted
   except between Normal & D.B. aided T.E.
   speaker for Fl of /o:/ rejected.
2. n.R. aided and L.P. aided T.E. speakers, accepted
3. D.B. aided and I.P. aided T.E. speakers accepted

4. L.P. aided and I.P. aided T.E. speakers accepted.

SPECTRAL MEASURES

Long Term Analysis of the Spectrum (LTAS)

17. Ratio of intensities between 0-1 KHz and 1-8 KHz (Alpha ratio)

Alpha ratio provides a measure of over all tilt of the sound spectrum (Lofqvist and Mandersson, 1987)

Group	Mean	S.D.	Range
Normal	3.69	.45	3.01-4.26
D.B.	3.48	.35	3.05-3.95
L.P.	3.52	.22	3.37-3.87
I.P.	3.54	.47	3.05-4.13

Table-26 :- The Mean, S.D. and Range of alpha ratio for normal, D.B., L.P and I.P. groups.

From Table-26 it can be infered that normals demonstrated higher Alpha ratio than T.E. speakers, but the demonstrated difference was minimal. It means to say that a high alpha ratio in T.E. speakers as in normals in this study indicated that the spectrum is dominated by the fundamental & lower harmonics resulting in the rapid falling of the LTAS curve. Among T.E.P. group higher Alpha ratio was notices in L.P. aided T.E. speaker and lower in D.B. aided T.E. speakers Results of present study were not correlating with the reports made by Rajashekhar (1991). He reported that alpha ratio in T.E. Speakers (L.P. aided) was considerably less (2.7) than in normals, and this may be due to the stomal air leak in some speakers owing to inadequate digital occlusion of the stoma and Puncture.

Wilcoxan test revealed that (Table-31) there is no significant difference between normal and T.E. speaker. Among

T.E. speakers, there was no significant difference across different prosthetic condition interms of alpha ratio.

The hypothesis stating that "there is no significant difference interms of alpha ratio between

1. Normal and T.E. speakers (with D.B., I.P & L.P.) accepted
2. D.B. aided and L.P. aided T.E. speakers accepted
3. D.B. aided and I.P. aided T.E. speakers accepted
4. L.P. aided and I.P. aided T.E. speakers accepted.

Thus, it was concluded that there are no significant differences between normal and T.E. speakers and among T.E. speakers across prosthesis interms of alpha ratio.

18. Ratio of intensities between 0-2 KHz and 2-8 KHz (Beta Ratio)

Table-27 show lower Beta ratio in T.E. speakers when compared with the normal group. This is due to higher intensity levels above 2 KHz in the T.E. speakers as compared to the normal group. Wilcoxoan test reveales (Table-31) no significant difference between the normal and T.E. speakers and within T.E.P. group across prostheses interms of Beta ratio.

Group	Mean	S.D.	Range
Normal	3.38	.38	2.89-3.77
D.B.	2.94	.33	2.57-3.34
L.P.	2.89	.40	2.27-3.34
I.P.	2.97	.53	2.41-3.56

Table-27:- The Mean, S.D. and Range of beta ratio for normal, D.B., L.P. and I.P. groups.

Beta ratio recorded in the T.E. speakers of the present study was similar to the results obtained by Rajashekhar, (1991) (2.7-L.P aided T.E. speakers). But in his study T.E. speakers differed significantly from the normals.

The hypotheses stating that "There is no significant difference interms of beta ratio between

1. Normal & T.E. groups (with D.B. L.P. and I.P.) accepted
2. D.B. aided and L.P. aided T.E. speakers accepted
3. D.B. aided and I.P. aided T.E. speakers accepted
4. L.P. aided and I.P. aided T.E. speakers accepted

19. Ratio of intensities between 2-5 KHz and 5-8 KHz (Gamma ratio) :-

Group	Mean	S.D.	Range
Normal	5.79	1.18	4.09-6.93
D.B.	4.49	.68	3.8 -5.43
L.P.	4.62	.55	4.04-5.47
I.P.	4.66	1.2	3.47-6.03

Table-28:- The Mean, S.D and Range of gamma ratio for normal, D.B, L.P and I.P. groups.

It can be infered from Table-28 that normals had higher gamma ratio when compared to T.E. speakers. It means that T.E. speakers showed more energy (intensities) above 5 KHz as compared to below 2 KHz. Wilcoxon test revealed that (Table-31) there were no significai: differences between normals and T.E.P. groups and within T.E.P. group across prosthetic conditions in terms of gamma ratio.

Rajashekhar (1991) reported gamma ratio for L.P. aided speakers (4.1) was significantly different from normals, but this was not noticed in the present study.

The hypotheses stating that "there is no significant difference interims of gamma ratio between

1. Normal and T.E. speakers, accepted
2. D.B. aided and L.P. aided T.E. speakers accepted
3. D.B. aided and I.P. aided T.E. speakers accepted
4. L.P. aided and I.P. aided T.E. speakers accepted.

PSYCHOACOUSTIC MEASURES

20. Acceptability:-

A five point scale with one being the 'most acceptable' and five being the 'least acceptable' was used to rate the acceptability of speech of subjects of all the four groups. Five judges (speech pathologists) rated the acceptability of speaker each for speaker individually. Table-29 depicts the judgements on the acceptability ratings of the four groups. It is seen that T.E.P. group was showing lower acceptability scores than normal speakers (Note:- one being most accepted and five being least aceptable) No significant difference were observed across different prosthetic condition in T.E. speakers, however, I.P. aided T.E. speakers showed better acceptability score than the other two groups.

Group	Mean	S.D.	Range
Normal	1.24	.43	1-2
D.B.	2.5	.8	2-4
L.P.	2.65	.83	1-4
I.P.	2.41	.62	1-3

Table-29:- The Mean, S.D. and Range of acceptability rating for normal, D.B, L.P. and I.P. groups.

For T.E. speakers acceptability rating score of this study was similar to as observed by Rajashekhar (1991) (2.7). The mean acceptability score of T.E. speakers were lower than normals as similar to reported by Blom et. al. (1986); Rajashekhar (1991).

Wilcoxon test indicated (Table-31) significant differences between normal and T.E.P. groups, however, no significant differences were noticed among T.E.P. groups across prosthetic conditions.

The hypothesis stating that "there is no significant difference in terms of acceptability across

1. Normal and T.E. speakers (with D.B., I.P. & L.P.) rejected
2. D.B. aided and L.P. aided T.E. speakers accepted
3. D.B. aided and I.P. aided T.E. speakers accepted
4. L.P. aided and I.P. aided T.E. speakers accepted.

21. INTELLIGIBILITY

Table-30 presents the mean intelligibility. Scores (percentage) computed from the scores of five judges for four groups.

Group	Mean	S.D.	Range
Normal	98.2	2.45	95.00-100
D.H.	76.33	12.42	36.84-95
L.P.	83.79	9.43	68.75-100
I.P.	80.10	8.61	63.16-95

Table-30:- The Mean, S.D. and Range of intelligibility (%) for normal, D.B. L.P. and I.P. groups.

T.E. speakers showed lower mean scores than the normals. Inspection of range indicated that there were speakers in T.E.P.

group who achieved scores with in the range of the normal group.

Though varying in their methodologies, studies have found mean word intelligibility scores for T.E. speakers ranged between 91.51% to 97%.

Mitzell et al, 1985 (93%), Blom et. al. 1986 (91.5%); Rajashekhar, 1991 (88.3%). In the present study, the mean intelligibility scores of T.E. speakers were lower than the scores reported by others.

Wilcoxon test revealed that the T.E. speakers differ significantly from normal speakers. (Table-31) There were no significant differences among groups T.E. speakers except L.P aided T.E. speakers who differed significantly from D.B. aided T.E. speakers however, the mean score showed that L.P. aided T.E. speakers obtained highest score and D.B. aided obtained least score.

The hypotheses stating that "there is no significant difference in terms of intelligibility between

1. Normal and T.E. speakers (with D.B., I.P. & L.P.), rejected
2. D.B. aided and L.P. aided T.E. speakers rejected
3. D.B. aided and I.P. aided T.E. speakers accepted
4. L.P. aided and I.P. aided T.E. speakers rejected.

Table-31 Summarizes the significant difference between the groups, interms of all the parameters studied.

Parameter		D.B. Vs N	L.P. Vs N	I.p. Vs N	D.B. Vs L.P.	D.B. Vs I.P.	L.P. Vs I.P.
1. FO in Phonation	/a/	S	S	S	S	NS	NS
	/i/	S	S	S	S	S	NS
	/u/	S	S	S	NS	NS	NS
2. FO in speech		NS	S	NS	NS	NS	S
3. Ex F.F.	/a/	S	S	S	NS	NS	NS
	/i/	S	S	S	S	NS	NS
	/u/	S	S	S	NS	NS	NS
4. SP F.F.	/a/	S	S	S	NS	NS	NS
	/i/	S	S	S	NS	NS	NS
	/u	S	S	S	NS	NS	NS
5. FR in Phonation	/a/	S	S	S	NS	NS	NS
	/i/	S	S	S	NS	NS	NS
	/u/	S	S	S	NS	NS	NS
6. FR in speech		NS	NS	S	NS	S	S
7. EX. F.I.	/a/	S	S	S	NS	NS	NS
	/i/	S	S	S	NS	NS	NS
	/u/	S	S	S	NS	NS	NS
8. Sp. F.I.	/a/	S	S	S	NS	NS	NS
	/i/	S	S	S	NS	NS	NS
	/u/	S	S	S	NS	NS	NS
9.IR in phonation	/a/	S	S	S	S	NS	S
	/i/	S	S	S	S	S	NS
	/u/	S	S	S	NS	S	S
10. IR in speech		S	S	S	NS	NS	NS
11. MPD	/a/	S	S	S	NS	S	S
	/i/	S	S	S	NS	S	S
	/u/	S	S	S	NS	S	S
12. RT	/a/	S	S	S	NS	NS	NS
	/i/	S	S	S	NS	NS	NS
	/u/	S	S	S	NS	NS	S
13. FT	/a/	NS	NS	S	NS	NS	S
	/i/	NS	NS	NS	NS	NS	NS
	/u/	NS	S	S	S	NS	NS

14	Vowel Duration :							
		/a/	NS	NS	NS	NS	NS	NS
		/i/	NS	NS	NS	S	NS	NS
		/u/	NS	NS	NS	NS	NS	NS
		/O/	NS	NS	NS	NS	NS	NS
		/E/	NS	NS	NS	NS	NS	NS
15	VOT	/P/	S	S	NS	NS	NS	NS
			NS	NS	NS	NS	NS	NS
		/K/	NS	NS	NS	NS	NS	NS
16	Formant frequences							
		Fl	NS	NS	NS	NS	NS	NS
		F2& F3	(except S-/o:/)					
			NS	NS	NS	NS	NS	NS
17.	Alpha Ratio		NS	NS	NS	NS	NS	NS
18.	Beta Ratio		NS	NS	NS	NS	NS	NS
19.	Gamma Ratio		NS	NS	NS	NS	NS	NS
20.	Acceptability		S	S	S	NS	NS	NS
21.	Intelligibility		S	S	S	S	NS	NS

P<.05
(Note :- S = Significant, NS = Non significant)
Table : 31 - Significance of difference between D.B. L.P. & I.P. aided T.E. speakers and normal speakers for all the parameters.

Table - 31 suggests that T.E. speakers (with all the three types of prostheses) did not differ significantly from normals on the parameters like vowel duration, VOT, formant frequencies, alpha ratio, beta ratio and gamma ratio. It means to say that T.E. speakers have VOT similar to normals for /t/ and/k/, for /p/ it was significantly different from normals for D.B. and L.P. aided T.E. speakers, where as it was similar to normals for I.P. aided T.E. speakers. So, interms of VOT I.P. aided T.E. speakers were found similar to normals. In terms of spectral measures (i.e., power spectrum of the speech) it was seen that T.E. speakers had more energy concentration in higher frequencies than normal speakers, however, no significant differnce was observed.

Other than these D.B. and L.P. aided T.E. speakers didnot differ significantly from normals in terms of frequency range in speech, D.B. and I.P. aided T.E. speakers did not differ significantly from normals interms of fundamental frequency in speech. As seen in Rajashekhar (1991) study, high correlation was noticed between intelligibility and acceptability and frequency range in speech, alpha, beta and gamma ratio. These all are the parameters found to be important to increase acceptabiliity and intelligibility of speech and in the present study these were similar to normals. So, it can be concluded that T.E. speakers can obtain acceptability and intelligibility scores near normal, but not exactly as normals because there are even other parameter which contributes for the acceptability & intelligibility which were significantly different from normals in the present study.

Among the T.E.P group, intensity range in phonation was the only parameter which significatnly differentiated all the three types of prosthese. L.P. aided T.E. speakers showed highest intensity range, I.P. aided T.E.speakers showed lowest intensity range. That means among T.E. speakers, I.P. aided T.E. speakers could maintain the intensity at a steady level than D.B. and L.P. aided T.E. speakers.

D.B. aided T.E. speakers differed significantly from L.P. aided interms of Fo in phonation, i.e., D.B. aided T.E. speakers showed high Fo than L.P. aided. This may be due to increased or more air resistance and effort in case of D.B. aided T.E.

speakers which inturn have increased the tension and led to higher Fo tham the low resistance (L.P.) prosthesis. I.P. aided T.E. speakers were lying some where in between the L.P. and D.B. aided T.E. speakers which didnot differ significantly from both of these B-S prosthesis.

I.P aided T.E. speakers differed significantly from D.B. & L.P. aided interms of frequency range (FR) in speech. FR in speech was found to be higher in I.P. aided T.E. speakers than D.B and L.P. aided and even higher than normal groups. It suggests that D.B. and L.P. aided T.E. speakers had FR near normal than I.P. aided T.E. speakers.

Apart from FR in speech, I.P. aided T.E. speakers differed significantly from L.P. aided interms of Fo in speech. Fo in speech was found near normal for I.P. aided T.E. speakers than the L.P. aided (and also D.B. aided) L.P. aided T.E. speakers differed significantly from normals, but I.P. aided didnot differ significantly from normals interms of Fo in speech. Thus, it can be concluded that I.P. aided T.E. speech is better than L.P. (and also D.B.) aided interms of Fo in speech. Also, I.P. aided T.E. speaker differed significantly from L.P and D.B. aided interms of maximum phonation duration (MPD). MPD was found to be longer in L.P. aided T.E. speakers than I.P. aided. No significant difference was found between L.P. aided and D.B aided T.E. speakers MPD, however, L.P. aided showed higher MPD than D.B. aided T.E. speakers. Thus, interms of MPD, L.P. aided was found to be better than D.B. and I.P aided & D.B. aided was better than I.P. aided T.E. speakers.

other than these acoustic parameters, intelligibility scores demonstrated significant differences between D.B. L.P. aided T.E.P. groups L.P. aided T.E. speakers showed higher intelligibility than the D.B. aided T.E. speakers where as I.P. aided T.E. speakers were lying some where in between L.P. and D.B. aided T.E. speakers which didnot differ significantly from both of the B.S. prosthesis. Thus, it can be concluded thatL.P. aided T.E. speech was better than I.P. aided and this (I.P. aided T.E. speech) was better than D.B. aided in terms of intelligibility.

From the above discussion it can be concluded that each one of the three prosthesis showed better results on some parameters than the other prostheses. However, it can be concluded that L.P. and I.P aided T.E. speech were better than DB aided speech . Among the L.P. and I.P. aided T.E. speech, L.P. had advantages over I.P. for MPD , FR in speech and intelligibility, where as I.P. aided speech was found to be better than L.P. aided for intensity range in phonation and in speech. Fo in phonation, alpha, beta and gamma ratio, rate of speech, MPD and FR in speech were the parameters which contributed significantly to the intelligibility and acceptaility of alaryngeal speech in Rajashekhar's study (1991). If you relate this with the present study it can be concluded that L.P. aides T.E. speech had advantage over IP aides speech in terms of MPD and FR in speech and these were the parameter which contributed for the intelligibility of speech. Even intelligibility scores of the L.P. aided T.E. speech is better than I.P aided T.E. Speech.

Hence, it can be concluded that L.P. aided T.E. speech is better than I.P aided T.E.speech which is better than D.B. aided T.E. speech.

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CHAPTER - V

SUMMARY AND CONCLUSION

Voice restoration following laryngectomy remains a challenging problem for both speech pathologist and Head and Neck surgeon. It is however, the key to return laryngectomees to productive life. Different methods for the restoration of voice following laryngectomy have been developed such as oesophageal speech, electronic/artificial larynx. But with the development of T.E.P. technique (Singer and Blom, 1980) , T.E. speech has become a widely accepted method of alaryngeal speech rehabilitation T.E. speech is achieved when pulmonany air is directed through the prosthesis to vibrate the P.E. segment and produce voice. At first Blom-singer's duck-bill prosthesis was developed. Later many prostheses were developed in different parts of the world to overcome the drawbacks of existing prothesis. so there was a need for studies producing information on different prosthesis in terms of acoustic and perceptual parameters. In this study it was possible to study B.S. duck-bill prosthesis, U.S. low pressure prosthesis and Indian prosthesis all being used by the same subject and they were compared with normals speakers in terms of acoustic and peruptual parameters.

The voice and speech sample from 5 T.E. speakers under three condition (i.e. 3 types of prosthesis) and 5 normal speakers were collected. These were analyzed using computer programmes and judges to obtain 21 parameters (acoustic, temporal, spectral, and psychoacoustic).

The results were subjected to stastical analysis using .... parametric statistical test - wilcoxon test for matched pairs (paired T-test). The following conclusions were drawn based on the statistical anaylysis.

I. The speech of T.E. speakers with prostheses were less acceptable and intelligible than the normal laryngeal speech. Among the T.E. speakers no significant differences were observed in terms of acceptability across prosthetic conditions and even in terms of intelligibility exception L.P. aided T.E. speakers which significantly different from the D.B. aided T.E. speakers.

II. 1. D.B. aided T.E. speakers didnot differ significantly from the normal laryngeal speaker on the following parameters :-

a. Fundamental frequency in speech
b. Frequency range in speech
c. Falling time
d. Vowel duration
e. voice onset time (VOT) (for /t/ & /K/)
f. Formant frequencies
g. Alpha Ration
h. Beta Ratio
i. Gamma Ratio

2. L.P. aided T.E. speakers didnot differ significantly from the normal laryngeal speakers on the following parameters :-

a. Frequency range in speech
b. Falling time
c. Vowel duration

d. VOT (For / t/ &/ K/)

e. Farmant frequencies

f. Alpha ratio

g. Beta Ratio

h. Gamma ratio

3. I.P. aided T.E. speakers didnot differ significnatly from the normal laryngeal speakers on the following parameters :

a. Fundamental frequencies in speech

b. vowel duration

c. VOT

d. Formant frequencies

e. alpha Ratio

f. Beta Ratio

g. Gamma Ratio

III 1. D.B. aided T.E. speakers differed significantly from the L.P. aided T.E. speakers on the following parameters.

a. Fundamental frequency in phonation

b. Intensity range in phonation

c. Vowel duration (Only for /i/ vowel)

d. Intelligibility

2. D.B. aided T.E. speakers differed significantly from the I.P. aided T.E. speaker on the following parameters.

a. Frequency range in speech

b. Frequency range in phonation

c. Maximum phonation duration

3. L.P. aided T.E. speakers differed significantly from the I.P. aided T.E. speakers on the following parameters : .

a. Fundamental frequency in speech

b. Frequency range in speech

c. Intensity range in phonation

d. Maximum phonation duration.

It is evident from the above finiding that low pressure prosthesis aided T.E. speech is better than Duck-bill and Indian prosthesis aided where as Indian prosthesis aided T.E. speech is better than Duck-bill prosthesis aided . This means that increased airflow resulting from use of the low pressure prosthesis had a postive impact on the parameters studied.

Recommendations :-

1. Other parameters may be considered for further study such as words per minute, total duration, total pause time, total number of pauses, mean pause time, percent pause time, syllable per second, % periodic phonation, % aperiodic Phonation, % silence

2. Parameters may be studied on a larger group.

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APPENDIX - 1

DEFINITIONS OF TERMS

1. **Tracheo-Esophageal Puncture (T.E.P.)** :

The surgical voice restoration method introduced by Singer and Blom (1980) where in, a middline puncture or fistula between the posterior wall of the trachea and the upper oesophagus is created endoscopically and into which the Blom-Singer's voice prosthesis is fitted.

2. **Tracheo-Oesophageal Speech (T.E. speech)**:

Speech produced by laryngectomees who have undergone T.E.P. and Blom-Singer's voice prosthesis fitting. Speech is produced when pulmonary air is directed through the prosthesis into the oesophagus to vibrate the pseudoglottis [Pharygoesophageal (PE) segment].

3. **Oesophageal Speech**:

Time honoured method of alaryngeal speech production wherein sound is generated by the vibrations of the P.E. segment with the release of the insufflated air in the oesophagus.

4. **Fundamental frequency in phonation (Fo)** :

The mean frequency (Hz) of the steady portion of phonation.

5. **Fundamental frequency in speech [Fo(Sp)]** :

The mean frequency (Hz) of the speech stimulus.

6. Extent of fluctuation in fundamental frequency in phonation (Ex.F.F.) :

The extent of fluctuation in frequency (Hz) Mas defined as the means of fluctuations in fundamental frequency in a phonation of one second.

Fluctuation in frequency was defined as variations +/- 3Hz and beyond in fundamental frequency.

7. Speed of fluctuation in fundamental frequency in phonation (Sp.F.F.) :

The speed of fluctuation in frequency was defined as the number of fluctuations in fundamental frequency in a phonation of one second.

8. Extent of fluctuation in intensity in phonation (Ex.F.I.) :

The extent of fluctuation in intensity (dB) was defined as the means of fluctuations in intensity in a phonation of one second.

Fluctuation in intensity was defined as variations +/- 3dB and beyond in intensity.

9. Speed of fluctuation in intensity in phonation (Sp.F.I.) :

The speed of fluctuation in intensity was defined as the number of fluctuations in intensity in a phonation of one second.

10. Frequency range in phonation (FR) :

The frequency range in phonation (Hz) was defined as the difference between the maximum and minimum fundamental frequency in phonation.

11. Intensity range in phonation (IR):

The intensity range in phonation (dB) was defined as the difference between the maximum and minimum intensities in phonation.

12. Frequency range in speech [FR(Sp)] :

The frequency range in speech (dB) was defined as the difference between the maximum and minimum fundamental frequency in speech.

13. Intensity range in speech (IR):

The intensity range in speech (dB) was defined as the difference between the maximum and minimum intensities in speech.

14. Maximum phonation duration (MPD) :

Maximum phonation duration (sec) has been defined as the maximum duration for which an individual can sustain phonation.

15. Rising time in phonation (RT) :

The rising time in phonation (msec) was defined as the time required for an increase in intensity from OdB to the beginning of the steady level of the intensity in the initial portion of the phonation.

16. Falling time in phonation (FT) :

The falling time in phonation (msec) was defined as the time required for the intensity to decrease from the steady level to OdB in the final portion of the phonation.

17. Vowel duration (VD) :

VD was defined as the duration (msec) between the onset as indicated by the initial periodic straiations of the first formant to the last vertical ctriations.

18. Voice Onset Time (VOT) :

Voice onset time (msec) was defined as the time interval between the burst that marks release of the stop closure and that reflected vibration for the following vowel (as defined by Lisker and Abramson, 1967).

19. Alpha ratio:

Ratio of intensities between O-lKHz and l-8KHz (alpha ratio).

Mean intensity of peaks in the frequency range O-lKHz

Mean intensity of peaks in the frequency range l-8KHz

20. Beta ratio:

Ratio of intensities between 0-2 KHz and 2-8KHz (beta ratio).

Mean intensity of peaks in the frequency range 0-2KHz

Mean intensity of peaks in the frequency range 2-8KHz

21. Gamma ratio :

Ration of intensities between 2-5KHz (gama ratio)

Mean intesity of peaks in the frequency range 2-5KHz

..

Mean intensity of peaks in the frequency range 5-8KHz

22. Formant frequencies Fl, F2, F3) :

Frequecnies of the first, second and third formant (Hz) as obtained from the spectrographic measurements. The formant frequencies were obtained by measuring the midpoint of the visible dark bands of energy, at a comparatively steady state portion of the vowel.

23. Intelligibility (INTL) :

Intelligibility (%) was defined as the words intelligible to the listener, i.e.

$$\text{Intelligibility} = \frac{\text{Number of words identified}}{\text{Total number of words}} \times 100$$

24. Acceptability (ACPTL)

Acceptability was defined as the rating on a 1-5 point scale, where 5 was the least acceptable and 1 was the most acceptable.

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APPENDIX - II

DETAILS ABOUT THE DIFFERENT TYPES OF PROSTHESIS

Name of the prosthesis	Inventor	Made of	Tube	Flange of the Proximal end (i.e. Oeso. side)	Flange of the distal end (i.e Tracheal side)	Slit or Valve	Duration (Life)	Device Removal
1) Blom-Singer's 'Duckbill' voice prosthesis	Blom & singer (1982)	Silicone	16-F diameter tube -3cm. long	5.4 mm in diameter (French no. 16)	Has a port on the inferior surface measuring 3.5 x 7mm for exhaled air entry	An 8 mm slit in the proximal end of the device act as one way valve		Daily removal for cleaning.
2) Blom-Singer's low pressure prosthesis	Blom, singers & Hamaker (1982)	Silicone	20-F diameter tube			2 mm slit hinged type circular valve in the proximal end.		
3) Panje voice Button	Willam R. Panje (1981)	Silicone	Biflanged tube - 7mm & 12 mm	10 mm in diameter	13 mm in diameter	Flutter valve located at the proximal end.	Several weeks to 8 months	Daily removal for cleaning,
4)Groningen Prosthesis or Standard Groninger button	Nijdam et. al. (1984)	Soft silicone material	Tube diameter 5mm & lengths of 3,5,7,9 11 & 13 mm.	12 mm in diameter	12 mm in diameter. It has a silicone string that is used for insertion & is removed afterwards.	Small straight slit in the hat of oesophageal flange.	Average 4-6 months (1-21 months)	It is self-cleaning prosthesis Doesn't need to be cleaned or changed by the patient.
5) H-C (Henley-Cohn) prothesis	Henley-Cohn (1984)	HEC doped Silicone		Act as retainer	Longer than tracheostoma to prevent inadvertent aspiration.	The valve tip was specially designed to minimise opening pressure & maximise air-flow.	Upto 8 months without removal during day or night. It is recommended that new prosthesis should be used at 3-4 months interval.	Same as Groningen prosthesis.

6)	Staffieri Mario & Staffieri Alberto	Food-grade Silicone	A semirigid hollow tube of 4 mm in diameter & come in 3 lengths 9 mm, 7mm, 5 mm.	22 mm in diameter soft & tapered	10 mm in diameter. A V-shaped cut in the Collar marks the position of the voice slit in the dome.	At the proximal end the tube is closed by a hemispherical dome into which a very short razar thin slit has been cut parallel to the base.	Average 8 months (6 to 12 months.		
7) Provox prosthesis	Hilgers J.M. Schouwenburg F.P., (1990)	Midial grade Silicone rubber.	8mm in length & also of 6 mm & 10 mm. Inner diameter 5 mm & outer diameter 7.5 mm.	14 mm in diameter. Rigid one.	12 x 16 mm oval shaped.	valve is moulded into one piece with the prosthesis & is supported by a ring made of fluoroplastic & is radiopague.	Mean 154 days (1 to 14 months)	Out patient replacement.	
8) Low resistance Groningen prosthesis	Zijlstra J.R. Mahieu F.H. Van Lith-Bijl T.J. Schutte K.H. (1991)	Silicone	Same as standard Groningen button	Same as standard Groningen button	Same as standard Groningen button	It has a semicircular slit in the hat of the oesophageal flange. It runs at a distance of 1 mm parallel to edge of the flange & at an angle of 42 to the horizontal. The radii from the ends of the slit form an angle of 145.			
9) Indian (HRD) prosthesis	Hazarika, Rajashekar & Derek	Silicone	Same as BS. D.B. but reinforced with armour for better retention & bellows.	Same as BS. D.B. prosthesis	Air flow port similar to BS. D.B. prosthesis for air entry.	Slit valve	Yet to be assessed		Atleast once a week/whenever ther is an obstruction due to secretion.

APPENDIX - III

LIST OF WORDS (KANNADA) USED AS TEST MATERIAL FOR

INTELLIGIBILITY ASSESSEMENT

1) ತಿರುಗಿ	t̪ i ṛ u g i
2) ರುಚಿ	r u t ʃ i
3) ಹೊಡೆದ	h o ḍ e d̪ a
4) ಹಗ್ಗ	h a g g a
5) ಏಟು	e: ṭ u
6) ಚಿಪ್ಪು	t ʃ i p p u
7) ಗುಂಜು	g u n d ʒ u
8) ಪ್ರದೇಶ	p r a d̪ e: ʂ a
9) ವಿದ್ಯುತ್	v i d̪ j u t̪
10) ಉತ್ಪಾದನೆ	u t̪ p a: d̪ a n e
11) ಜನರು	d ʒ a n a r u
12) ಬೇಲೂರು	b e: l u: r u
13) ಆಣೆಕಟ್ಟು	a ṇ e k a ṭ ṭ u
14) ತಿರುಗು	t̪ i r u g u
15) ನೋಣ	n o ṇ a
16) ತಪ್ಪಿಸಿ	t̪ a p p i s i
17) ಸಮಾಜ	s a m a j a
18) ಕರ್ನಾಟಕ	k a r n a: ṭ a k a
19) ನಾರು	n a: r u
20) ಬುದ್ಧಿ	b u d̪ d̪ h i
21) ಹಾಸಿಗೆ	h a: s i g e
22) ಊರು	u: r u
23) ಅಡಿಗೆ	a ḍ i g e
24) ಮನುಷ್ಯ	m a n u ʃ j a
25) ಭೀಮಾ	bʰ i: m a

26) ನಮ್ಮ	n̪ a m m a
27) ನೋಡಲು	n o: ḍ a l u
28) ನಂದಿ	n a n d̪ i
29) ಕೊಬ್ಬರಿ	k o b b a r i
30) ಬೆಂಗಳೂರು	b e ŋ a ḷ u: r u
31) ರಾಗಿ	r a: g i
32) ಹಳದಿ	h a ḷ a d̪ i
33) ಕೆಲವು	k e l a v u
34) ಕೆಲಸ	k e l a s a
35) ರಾಜ್ಯ	r a: dʒ j a
36) ಎಳನೀರು	e ḷ a n i: r u
37) ಬೊಂಬಾಯಿ	b ɔ m b a: j i
38) ಕೃಷ್ಣಾ ನದಿ	k r i ʃ ṇ a: n̪ a d̪ i
39) ಜಮಖಾನ	dʒ a m a kʰ a: n̪ a
40) ಹಾನಿ	h a: n̪ i
41) ಪರ್ವತ	p a r v a t̪ a
42) ಜೋಗ	dʒ o g a
43) ಸರಿಯಾಗಿ	s a ṛ i j a g i
44) ಬರುವರು	b a ṛ u v a r u
45) ಹಸಿರು	h a s i r u
46) ದೊಡ್ಡ	d̪ o ḍ ḍ a
47) ಬೇಸಿಗೆ	bɛ:s i g e
48) ಕಚ್ಚು	k a tʃ tʃ u
49) ಗುಂಡು	g u n ḍ u
50) ಪ್ರಾಣಿಗಳು	p r a: ṇ i g a ḷ u