"ACOUSTIC ANALYSIS OF SPEECH OF GLOSSECTOMEE'S"

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All India Institute of speech and Hearing

Mysore - 570 006

May 1999

DEDICATED TO AMMA, APPA,

GEETHA & PUNEETH

CERTIFICATE

This is to certify that this dissertation entitled **"ACOUSTIC ANALYSIS OF SPEECH OF GLOSSECTOMEE**'S" is the bonafide work in part fulfillment for the degree of Master of Science (Speech and Hearing) of the student with register number M -9702.

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This is to certify that this dissertation entitled **""ACOUSTIC ANALYSIS OF SPEECH OF GLOSSECTOMEE'S"** has been prepared under my supervision and guidance.

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DECLARATION

This dissertation entitled **"ACOUSTIC ANALYSIS OF SPEECH OF GLOSSECTOMEE'S"** is the result of my own study under the guidance of **Dr.N.P.NATARAJA,** Professor and Head Department of Speech Sciences, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any University for any other Diploma or Degree.

Place : Mysore M - 9702.

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INTRODUCTION

During the thirties, forties and early fifties the adventure movies were acquainted with the dramatic moment, when, in the presence of the assembled court, the king declares with anger, "Take him thither ! Tear out his tongue !". The poor messenger who brought the news of the lost battle is then dragged from the room to be forever silenced. This has been perhaps the long tradition of silencing the individual through tongue removal which has contributed to the lack of creative research and clinical endeavor with the glossectomee.

Tongue is the most important and most active of the articulators and it occupies the major area of the floor of the mouth. It consists of two parts, the body and the root. The tongue is not only the most important organ in the perception of the gustatory sensation but also has a significant motor part in the mechanism of mastication and deglutition. These activities of the tongue are described as primary. Great flexibility and mobility of that organ play a role in the secondary function, that is in articualtion of consonants and vowels either lingual or palatal. It functions to modify the shape of the oral cavity and thus the resonance characteristics of the oral and associated cavities. The tongue also acts as a valve to either inhibit or stop the flow of air and in conjunction with the teeth, alveolar process, and palate, may act as a noise generator. At times, it functions both as noise generator and a modifier of the laryngeal tone, as in the production of voiced consonants.

Hence, the tongue is a very remarkable structure, able to assume many different configurations and positions in anazingly rapid sequences.

Hard castle (1976) lists seven articulatory parameters which can account for the wide range of tongue positions and configurations during speech. The parameters are as follows:

a. Horizontal forward - backward movement of the tongue body -> for low back vowels.
b. Vertical upward - downward movement of the tongue body -> for central vowels and for palatal consonants.
c. Horizontal forward - backward movement of the tip blade -> important in retroflex articulations.
d. Vertical upward - downward movement of the tip blade -> used in production of /i/, /t/, /n/ and /s/.

e. Transverse cross - sectional configuration of tongue body, convex - concave in relation to palate -> used in production of /t/.

f. Transverse cross sectional configuration extending throughout the whole length of the tongue, particularly the tip and blade - degree of central grooving -> used in production of /s/.

g. Surface plane of the tongue dorsum - spread or tapered -> used in production of /t/ /s/ /1/ /i/ and /e/.

Therefore tongue is believed to be one of the most important articulatory organs (Brodnitz, 1960).

The American Cancer Society in its cancer Facts and Figures (1971) stated that five percent of all cancers occur in the oral cavity and carcinoma of the tongue is ranked as the second most frequent form of oral cancer. Chronic inflammatory conditions such as syphilitic glossitis and stomatitis seem to be predisposing to cancer. Long standing trauma to the oral mucosa by sharp, defective teeth or ill fitting dentures is also considered by some authorities to be a contributing cause of oral cancer. Primary cancer of the tongue is the most frequently met malignant neoplasm of the oral cavity. Most tongue cancers appear on the lateral surface although they arise on the superior or inferior surfaces. The most posterior the lesion, the more malignant it becomes. It may be the ulcerative infiltrating type or the fungating, papillary type of lesion. A third type of malignant lesion, the fissure type, may occur at the junction of the lateral base of the tongue and the anterior tonsilar pillar.

Among the Benign tumors of the tongue , the ones most frequently observed are neuroma, fibroma and lipoma. These tumors, if not of a critical size, do not affect the articulation of speech sounds. Likewise, the tongue goitre does not impede articulation: it can only influence the sound of speech. Direct injuries of the tongue are met quite often during wartine: during periods of peace these lesions are the consequences of accidents (eg. electrocutting in children) or surgical treatments for malignant tumors. Jeppsson et al (1975) reported among 177 patients with malignant tumors of the oral cavity, lingual neoplasms were noted in 54% of cases. Cancer of the tongue is also the most frequent among other neoplasms of that organ and it occurs three times more often in men than in women.

For patients with cancer of tongue, the operative approach is the only method of treatment with a appreciable three year survival rate (Donaldson et al, 1968). This surgery is called the "glossectomy" and the person who undergoes glossectomy is called "a glossectomee". A large proportion of the glossectomee population have additional surgical alteration such as hemimandibulectomy. Some are also laryngectomees. The skills of modern plastic surgery have extended the life span of many cancer patients. As a result, an increasing number of persons who have lost portions of the mechanisms for mastication, deglutition, phonation and articulation are left with consequent severe disabilities. Laryngectomy causes loss of voice. Glossectomy prevents normal articulation of the speech sounds. If a portion of the jaw is removed, additional dental and mandibular problems ensure. Mandibular excursion and labial movement may be limited. Dysphagia or regurgitation may occur. The palate is often included in the resection or suffers scarring contraction or loss of soft palate motility. Hyper rhinolalia will distort any existing speech, so that intelligibility will be negligible.

A patient with total glossectomy may present two primary rehabilitative problems, namely,

a. Eating and swallowing

b. Speech

With no tongue to manipulate and direct substances in the oral cavity, management of food and protection of airway are jeopardized. Drooling of saliva from the mouth is a common problem with considerable psychological and social drawbacks. Drooling is more of a problem when only part of the tongue is removed. The total glossoctomee rarely drools, although he will tend unavoidably to spit saliva as he tries to talk.

Vowels, semi vowels and lingual consonants are the speech segments most seriously affected by a glossectomy procedure, though acoustic characteristics of all speech sounds may be influenced by the altered vocal tract.

Principally because the speech distortions consequent to total tongue excision have been largely regarded as irreversible, little has been done to assist speech rehabilitation of total glossectomees. However speech rehabilitation may be started prior to the removal of the tracheostomy tube, perhaps as early as the tenth postoperative day and continue until the speech pathologist believe the patient has achieved his best possible speech.

Speech may be improved by adopting compensatory articulatory techniques (Skelly et al 1971). Instances of persons developing reasonably intelligible speech following removal of part or all of the tongue cast serious doubt upon the notion that the tongue is indispensible and that without it speech would be virtually impossible.

Froeschels (1933) cited cases of glossectomized individuals who were able to regain satisfactory speech. He indicated that this was possible because of muscular contractions of the tongue stump as well as the development of compensatory movements by the remaining structures.

To understand the speech sounds of a language it is necessary to learn about the articulatory and acoustic nature of the speech sounds. The speech sounds are percieved by the human being as an acoustic event. These acoustic events are the consequence of articulatory movements. The study of acoustic characteristic of speech sounds will give information about the articulatory nature of the sound and also how these sounds are percieved. (Picket 1980).

Acoustic analysis of speech sounds provides information about the source characteristic of fundamental frequency (F0), intenstity etc., Filter characteristics like formant frequency, fonnant bandwidth etc., and the temporal characteristics like vowel duration, closure duration etc., apart from spectral characteristics.

AIM OF THE STUDY:

The aim of the study was to compare acoustic and temporal aspects of glossectomee speech with the normal speech and to note the difference between the two to consider the clinical implications.

HYPOTHESIS:

The following hypothesis were proposed for the study.

1. There is no significant difference between glosectomee speakers to that of normal speakers in terras of:

a. Total word duration
b. Vowel duration
c. Closure duration
d. Voice onset time
e. Burst duration
f. Burst frequency
g. Formant frequencies of vowels,
h. Bandwidth.

2. There is no significant perceptual difference between the glossectomee speech and normal speakers.

The present study aimed at comparing the glossectomee speech and normal speech at word level to determine the similarities and differences between the two. The parameters studied were,

- Formant frequencies (Fl, F2, F3)
- Bandwidth (Bl, B2, B3)
- Burst frequency
- Vowel duration
- Closure duration
- voice onset time
- Burst duration
- Total word duration
- Acceptability and intelligibility

Ten Malayalam (Five normals and Five glossectcmee) speakers participated in the study. The subjects were instructed to produce twenty six words followed by a carrier phrase. They were also instructed to read a standard Malayalam passage.

The speech samples were recorded in a sound treated room. Recordings were made on hi-bias metal cassettes, using a professional stereo cassette deck (Ahuja) and a AKG - D 222 dynamic cardioid microphone with a flat frequency response from 50-15,000 Hz. The microphone to mouth distance was approximately 10 cm for all the subjects.

For analysing the data, tape deck, antialiasing filter, A-D/D-A converter, PC, amplifier, speaker and a software developed by voice speech system, Bangalore was used.

LIMITATIONS:

1. The number of glossectomy subjects were limited to five.
2. Gender as a variable was not controlled.
3. Type of surgery was not controlled.

IMPLICATIONS:

-> Better understanding of speech of glossectomees in an Indian language i.e., Malayalam

-> It gives data regarding the acoustical characteristics of speech of glossectomees.

REVIEW OF LITERATURE

"One form of communication which people use most effectively in inter-personal relationship is speech. Through it, human beings give out their innermost thought, their dreams, ambitions, sorrows and joys. Without speech, they are reduced to animal noises and unintelligible gestures. In real sense, speech is the key to human existence. It bridges the differences and helps to give meaning and purpose to their lives." (Fischer, 1975).

"Human being is a social animal with higher cognitive and symbolic processing capabilities. These unigue capabilities of human being were possible because of his ability to communicate effectively and efficiently". (Dance and Larson, 1972).

Travis (1971) defines communication as the process by which the individual interacts with his or her environment and with himself or herself. In the process of communication the individual relates and exchanges experiences, ideas, knowledge and feelings with others through symbols and transmits those symbols either through acoustical or through visual modes. For communication, human beings use several symbolic systems, eg., speech, sign language, writing, singing, morse code. . . . . .etc., speech is one of the most commonly used and efficient modes of communications.

Skinner and Shelton (1978) define speech as the process of encoding a linguistic message by producing coded vocal patterns which carry the meaning. It is well known that no one definition can encompass all aspects of "speech" completely.

According to Fant (1960) "Speech is a form of communication in which the transmission of information takes place by means of speech waves which are in the form of acoustic energy. The speech waveform is the result of the interaction of source and filter".

$$P = S \times T$$

Where, P = Speech

S = Source, mainly glottal pulses

T = Transfer function of the vocal tract.

Thus the speech is a coded complex acoustic signal which is produced by the action of vocal tract and has an encoded linguistic message.

To understand the nature and function of speech sounds, it is necessary to know the mechanism involved in their production. Speech production is a process where the concepts, ideas and feelings are converted into linguistic code ; linguistic code into neural code ; neural code into muscular (articulatory) movement and finally muscular movement leads to acoustic signal (Ainsworth, 1975). Hence, speech is just a particular type of acoustic signal and its production can be explained in terms of resonances of the vocal tract, and it can be analyzed into its component frequencies by conventional methods.

The apparatus used for speech production, the vocal tract evolved primarily as a part of the respiratory and digestive systems. Human beings have learnt to use these systems to produce speech. Vocal apparatus consists of the lungs, trachea, larynx, pharyngeal, oral and nasal cavities. In the process of breathing, air is drawn into the lungs by expanding the rib cage and lowering the diaphragm. This reduces the pressure in the lungs and air flows in, usually via nostrils, nasal tract, larynx and trachea. The air is normally expelled by the same route, by contracting the rib cage and relaxing the diaphragm. This increases the air pressure in the lungs and the air flows out. Human beings have learnt to use these systems to produce speech.

While speaking, the lungs are filled with air and the pressure inside the lungs is increased by the contraction of rib cage and diaphragm. This increase in pressure forces the air from the lungs to the environment. At the superior end of the trachea, their is a structure known as larynx. The larynx is a valvular system consisting of three valves. The lower most valve is formed by vocal folds and is made up of ligaments and muscles. The orifice between vocal folds, the glottis, is opened by the pressure of expiratory air. Once the vocal folds are opened the pressure below the vocal folds reduces due to the escape of air. As the air flows through the glottis, the subglottal pressure is reduced. The airflow from subglottal cavity to supra glottal cavity through a narrow opening, leads to a negative pressure at the glottis, and draws the vocal folds together which can be explained using the Bernoulli principle. The elasticity of the vocal folds also helps in drawing the vocal folds to the midline. As the vocal folds close, the pressure again builds up, forcing the folds apart and the cyle is repeated, thus the vocal folds are set into vibration. This process produces a weak quasi-triangular acoustic signal and is known as phonation. The quasi-triangular air pulses so produced excite the resonance cavities in the oral and nasal tracts. The sound will radiate from lips or from the nostrils depending upon the closing and opening of the velopharynageal port respectively. The rate at which the rib cage and diaphragm. This increase in pressure forces the air from the lungs to the environment. At the superior end of the trachea, their is a structure known as larynx. The larynx is a valvular system consisting of three valves. The lower most valve is formed by vocal folds and is made up of ligaments and muscles. The orifice between vocal folds, the glottis, is opened by the pressure of expiratory air. Once the vocal folds are opened the pressure below the vocal folds reduces due to the escape of air. As the air flows through the glottis, the subglottal pressure is reduced. The airflow from subglottal cavity to supra glottal cavity through a narrow opening, leads to a negative pressure at the glottis, and draws the vocal folds together which can be explained using the Bernoulli principle. The elasticity of the vocal folds also helps in drawing the vocal folds to the midline. As the vocal folds close, the pressure again builds up, forcing the folds apart and the cyle is repeated, thus the vocal folds are set into vibration. This process produces a weak quasi-triangular acoustic signal and is known as phonation. The quasi-triangular air pulses so produced excite the resonance cavities in the oral and nasal tracts. The sound will radiate from lips or from the nostrils depending upon the closing and opening of the velopharynageal port respectively. The rate at which the vocal folds vibrate depends upon its tension, mass, length and the sub glottal air pressure. The sounds generated by the vibration of vocal folds are known as voiced sounds. The voiceless sounds, are produced by a turbulent flow of air caused by a constriction at some point in the vocal tract. This constriction may be formed by the lips, the tongue or the velum. Another source of excitation can be created by closing the vocal tract completely or partially at some point, allowing the pressure to build up, and then suddenly releasing it or creating the friction of air. This form of excitation is employed in the production of plosive or fricative consonants. Whispered speech is produced by partially closing the glottis so that the turbulent air flow replaces the periodic excitation during voicing.

The modulated or unmodulated airflow through the glottis is further modified by the vocal tract to form speech sounds, which are mainly divided into vowels and consonants. The consonants can again be classified based on the place and manner of articulation. The classification of the consonants based on manner and place of articulation is given in the International phonetic alphabet (revised to 1993, corrected 1996) chart (Table 1).

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TABLE-1: The international phonetic alphabet chart

THE INTERNATIONAL PHONETIC ALPHABET (revised to 1993, corrected 1996)

CONSONANTS (PULMONIC)

	Bilabial	Labiodental	Dental	Alveolar	Postalveolar	Retroflex	Palatal	Velar	Uvular	Pharyngeal	Glottal
Plosive	p b			t d		ʈ ɖ	c ɟ	k ɡ	q ɢ		ʔ
Nasal	m	ɱ		n		ɳ	ɲ	ŋ	ɴ		
Trill	ʙ			r					ʀ		
Tap or Flap				ɾ		ɽ					
Fricative	ɸ β	f v	θ ð	s z	ʃ ʒ	ʂ ʐ	ç ʝ	x ɣ	χ ʁ	ħ ʕ	h ɦ
Lateral fricative				ɬ ɮ							
Approximant		ʋ		ɹ		ɻ	j	ɰ			
Lateral approximant				l		ɭ	ʎ	ʟ			

Where symbols appear in pairs, the one to the right represents a voiced consonant. Shaded areas denote articulations judged impossible.

The production of vowels and consonants are explained below briefly.

a. VOWEL PRODUCTION:

The vowels are produced by voiced excitation of the vocal tract. For the production of a vowel the vocal tract normally maintains a relatively stable shape and offers minimal obstruction to the air flow. This facilitates the laminar flow glottal pulses through the vocal tract. During the production of vowels, the velum is normally elevated to prevent the excitation of the nasal tract.

The production of vowel can be explained through source filter theory. For vowel production the source filter theory states that the output energy is a product of the source energy and the resonator. The source filter theory of vowel production can be summarized as,

$$P(f) = U(f)\ T(f)\ R(f).$$

Where,

P(f) is the radiated sound pressure spectrum of speech. 'P' stands for pressure and (f) indicate a function of frequency. 'U' refers to volume velocity and is used because the vocal folds act like a source of air pulses. 'T' represents transfer function, and 'R' denotes radiation characteristics.

In other words, the radiated sound pressure waveform of speech is the product of the laryngeal spectrum, the vocal tract transfer function, and the radiation characteristics.

Different vowel can be described as variations in the transfer function, T(f), and the radiated spectrum P(f). T(f) consists of vowel formants.

For the vowel production, the entire vocal tract, extending from larynx to lips, is the resonating cavity.

The figure 1 shows the vocal tract configurations and corresponding area functions for four vowels /i/, /u/ /a/ and /a?/.

The vocal tract configuration for these vowels have some relatively constricted regions and other regions that are widely flared. For example, vowel /i/ (as in he) has a constricted region near the lip opening but a large open region near the larynx and pharynx. The vowel /a/ (as in ha) has a constricted region in the pharynagel portion but a large open region near the lip opening. The resonance frequencies of such configurations can be calculated using formulas from acoustic theory.

The production of vowels can also be explained through the vowel diagram (Fig, 2), which explains the position of the lower jaw and tongue in producing vowels.

The position of /i/ at the upper left hand corner indicates that /i/ is pronounced with the tongue high and front in the mouth ; /a/ with the tongue low and front ; /a/, with the tongue low and back, and /u/ with the tongue high and back.

The sounds /I/ /e/ */€/* and / / are all made with the tongue front, and with the jaw and tongue dropping progressively by approximately equal distances from /i/ through /I/, /i/, */€/* and */as./* to /a/ . The sounds /o/, /o/. /0/ and /U/ are made with the tongue back, and with the jaw and tongue rising progressively by approximately equal distances from /a/ through */o/,* /O/, *lot* and /U/ to /u/. The sounds /3/, /a/, *l$l* and /sry are central made with the tongue about halfway from the front toward the back, and about halfway from low toward high. The sound /^/ in American speech is somewhat centralized but is lower and farther back than the central vowels.

The spectra of the four vowels /i/, /u/, /a/, and */3eJ* are given in the figure 3.

Figure 1: Vocal tract configurations and corresponding area functions for four vowels /i/, /u/, /ɑ/ and /æ/.

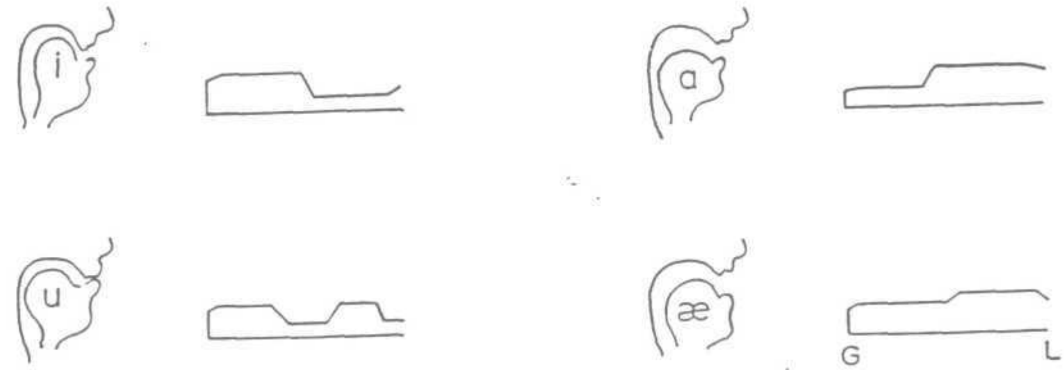


Figure 2 : Vowel diagram.

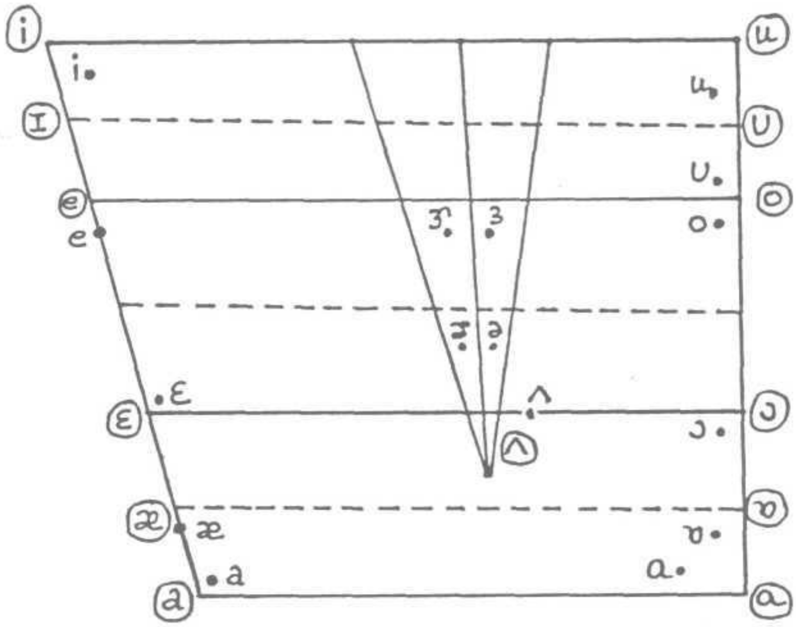
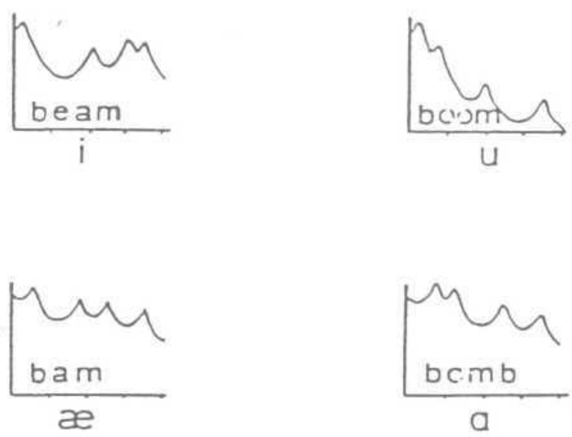


Figure 3 : Spectra for the four vowels /i/, /u/, /ɑ/ and /æ/.



The spectral peaks represent the vowel formants. It can be noted that the high vowels /i/ and /u/ have in common a relatively low frequency of the first formant (fl)/ whereas the low vowels /a/ and /ae/ have in common a relatively high frequency of this formant. That is the frequency of Fl, varies inversely with tongue height of the vowel.

The back vowels /u/ and /o/ have a relatively low frequency of the second formant (F2), whereas the front vowels /i/ and /ae/ have a relatively high frequency for this formant. That is, the frequency of F2 varies with the posterior to anterior dimension of the vowel articulation.

This result points to an articulatory-acoustic correspondence: The frequencies of the first two formants, Fl, and F2, can be related to dimensions of vowel articulation. The frequency of Fl, is inversely related to tongue height and frequency of F2 is related to tongue advancement. Hence, when the Fl frequency decreases, it is usually safe to conclude that the tongue has moved to a higher position. When the F2 frequency increases, it is usually safe to conclude that the tongue has moved to a more anterior position.

The lips are also involved in vowel production. Lip rounding reduces all the formant frequencies. The reason follows directly from the fact that formant frequencies depend on the length of the vocal tract. The longer the length, the lower the formant frequencies. Because lip rounding tends to extend the length of the vocal tract, rounded vowels tend to have lowered formant frequencies relative to nonrounded vowels.

The formant frequencies play an important role in the perception of vowels. The acoustic cues to the perception of vowels lie in the patterns created by the vocal tract resonances (formants) of the speaker. The formant patterns by themselves, however, are not always sufficient for listener identification. In the early 1950's Delattre, Liberman, Cooper and Gertsman at Haskin's laboratories synthesized vowels by painting formants on the pattern playback, systematically varying the formant frequencies, in search for the best patterns for listener identifications of each vowel. It was found that listener required only two of the formants naturally produced, in order to identify the vowels. They also found that although two formants were required for front vowels, a single formant could be used to approximate the back vowels.

In Gunnar Fant's laboratory in Sweden, it was found that the best two-formant synthetic vowels differ systematically from natural vowels. For /i/, the F2 must be very high, close to the natural F3, while for the rest of the front vowels, the F2 was best placed between what would naturally be F2, and F3. Back vowels were best synthesized with the F2 close to a natural F2. For speech perception, apparently F3 is more important for front vowels than for back vowels.

Perception of vowels is easy because they are voiced and thus relatively high in intensity ; the vocal tract is relatively open for them, producing prominent resonances ; and the formant frequencies are often held steady for a 100 *msec* or so, allowing the listener to perceive the formant pattern.

Fry, Abramson Eimas and Liberman (1962) synthesized vowels using the formant frequencies estimated from natural speech and they report of satisfactory results.

Rakerd and Verbrugge (1985) reported significant correlations between perceptual dimensions and acoustic parameters of vowels: Dimension Dl, (interpreted as advancement) with F2 and F3 frequency : Dimension D2, (interpreted as tenseness) with duration. They also report that low vowels have a high Fl frequency and high vowels have a low Fl frequency. Back vowels have a low F2 and a small F2-F1 difference, and front vowels have a higher F2 frequency and a large F2-F1 difference. Hence, vowels formant pattern can be used to identify a vowel and even to establish relationships between acoustic and perceptual parameters.

Fox (1983) concluded that the most common dimensions in perceptual scaling studies of vowels correspond to front/back (advancement) and high/low (height) distinctions.

Carlson, Fant and Granstrom (1975) reported a study in which Fl was held at values appropriate for natural speech but F2 was varied. They found that F2 approximated the value for F2 in natural speech for back vowels. For front vowels, F2 for vowels /e/ and /ae/ fell about midway between the natural F2 and F3 and for vowel /i/, F2 fell close to the natural F4.

b-FRICATIVE:

The steps in producing a fricative sound are to, make a constriction somewhere in the vocal tract, and force air at high velocity through the constriction. The turbulent flow is generated in the vicinity of the constriction and also at the teeth in some cases. The turbulent flow is characterized by eddies of particle motion and is the source of turbulence noise. This noise excites the acoustic tube that forms the constriction and also the cavities anterior to the constriction. Under certain conditions, there may be an acoustic coupling to the cavities posterior to the construction, so thse cavities are also excited. The figure 4 shows a vocal tract configuration for the fricative sound /s/ and a two-cavity model for this sound.

The dot near the constriction represents the location of the noise source.

Like vowels, fricatives can be described mathematically in terms of a transfer function. For fricatives, the function is,

T(f) = [P(f) Z(F)] R(f), where

T(f) = Transfer function,

(f) = frequency

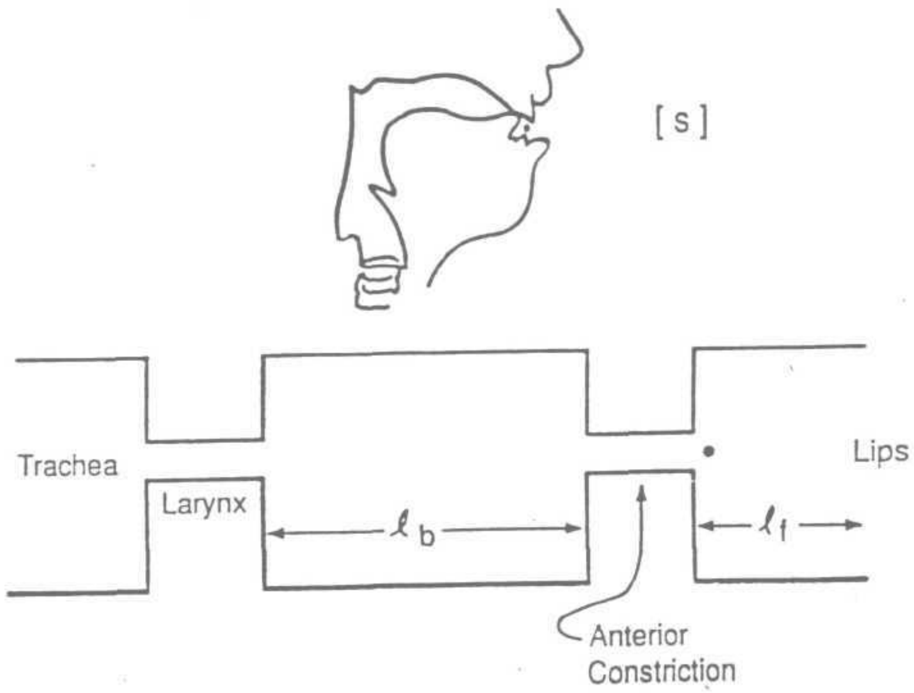
P(f) = Function, that contains the natural frequencies of vocal tract (poles or formants)

R(f) = Radiation characteristic

Z(f) = Function containing the zeros (antiformants) which occur at frequencies at which the source is decoupled from the front cavities.

23.a.

Figure 4 : Vocal tract configuration and a two cavity model for the fricative sound /s/.



The functions P(f) and R(f) are similar as for vowel sound. The poles are the resonance frequencies. The pole function P(f) for the fricative is approximately the same as that for a vowel produced with a similar vocal tract shape. The radiation function R(f) is as described for vowels. The function Z(f) represents zeros. Zeros are effective opposites of poles.

When the coupling between source and back cavities is small, the influence of the back cavities can be neglected, and the zeros are determined only by the constriction. However when the back cavity has a tapered shape leading into a constriction, the back cavity is not decoupled from the source.

The effect of front cavity is largely determined by its length. When the front cavity is very short, as in the case of the labiodental fricatives. /f,v/, its lowest resonance frequence is too high. The spectrum for these fricatives is flat or diffuse, lacking prominent peaks or valleys. As the place of articulation moves backward in the oral cavity, the length of the front cavity increases, and its lowest resonance frequency decreases. The lowest resonance frequency for a fricative /s/ is around 4Khz.

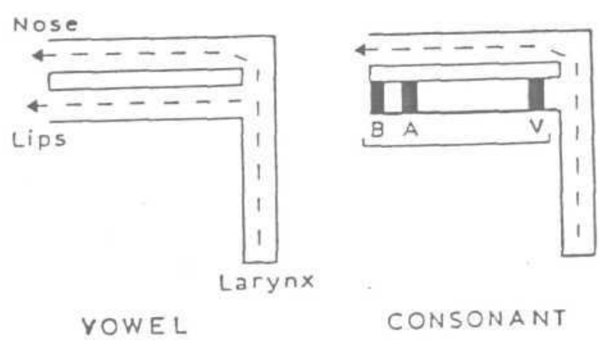
c. **NASALS:** The nasal sounds include nasalized vowels and the nasal consonants. The velopharyngeal port is open so that sound energy can pass through both the nasal tract and the oral tract or through only the nasal tract. These two vocal tract configurations can be modelled as shown in the figure.5.

Both models involve a side-branch resonator, meaning that one resonator is coupled to another at the velopharyngeal port. For a nasal vowel, both resonators open to atmosphere. For nasal consonants, the nasal resonator opens to atmosphere while the oral resonator is closed.

For both nasal vowels and consonants, the transfer function consists of poles and zeros. As with fricatives, nasals can be understood in part through a consideration of the average spacing of formants and antiformants. The formants and antiformants of the nasal cavity depends on the length of the nasal cavity. Hence, the combined oral-nasal system has a set of oral formants, a set of nasal formants and a set of nasal antiformants.

When the oral cavity is closed at some point for a nasal consonant, the frequencies of the antiformants are the frequencies at which the mouth cavity shortcircuits, transmission through the nose. Energy at these frequecny does not pass through the nasal cavity. The nasals */m/,* /n/ and

Figure 5 : Vocal tract models for a nasalized vowel and nasalized consonants.



/v) / are characterized by low (750-1250Hz) medium (1450-2200Hz) and high (above 3000Hz) artiformant positions respectively. Hence, the general rule is that as the place of oral articulation moves back, the frequency of the antiformants increase. A low frequency formant, the so-called nasal formant, occurs at about 250-300Hz. Higher formants are densely packed, have large bandwidths, and vary with place of articulation.

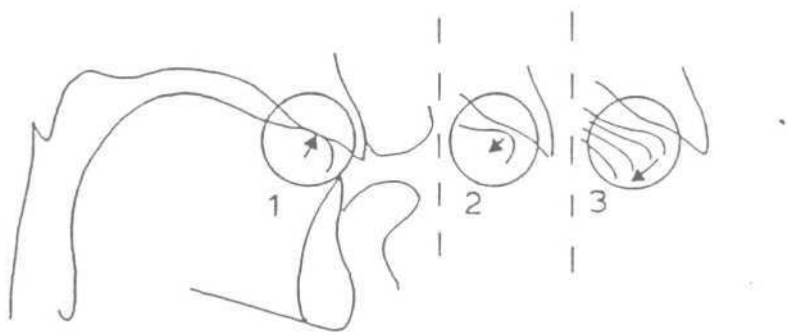
d. STOPS:

A stop involves a complete closure of the vocal tract, and , depending on its phonetic context, a release of the closure and a movement toward another vocal tract configuration. The closure is associated with acoustic silence. During the closure interval, air pressure is impounded in the mouth. Upon release of the constriction, the pressure is abruptly released.

The acoustic evidence of this release is a burst or transient. The brust is a noise segment similar to the noise segment for a fricative but much briefer. The event in stop production can be modelled as shown in figure. 6.

The primary acoustic correlate is silence, except for voiced stops, for which voicing energy may extend for part or

Figure 6 : Events in the production of stop consonants.



all of the closure Interval. Voicing is associated with low frequency energy in the lower harmonics of the voice source, especially the first harmonic or fundamental frequency. The Fl frequency associated with any severe constriction of the vocal tract is of very low frequency. As the constriction is released, the Fl frequency rises to a value appropriate for the following sound.

E. AFFRICATES:

Affricates are similar to stops in having a two-phase production of vocal tract closure followed by a noisy release. Affricates have a frication segment that is intermediate in duration between the burst for stops and the frication interval for fricatives. Hence, the basic theory of affricate production is a modification of that presented for stops and fricatives.

F. LIQUIDS:

The liquids in english are the lateral /I/ and the rhotic /r/. Both are similar to vowels in that they have well defined formant patterns and voiced energy. Lateral consonant /I/ have both formants and antifomants and are therefore similar to nasal consonants. The /I/ is produced with a midline apical constriction, which allows sound to radiate through openings at the sides. This midline bifurcation causes the formation of artiformants. /1/ has a relatively low acoustic energy with a predominately low frequency concentration.

Rhotic consonants /r/ have well defined formant patterns but are typically less intense than surrounding vowels. /r/ has a very low F3 frequency.

G. DIPHTHONGS AND GLIDES:

Another class of sounds, related to vowels, is the diphthongs. Diphthongs are like vowels, in that they are produced with a relatively open vocal tract and a well defined formant structure. Diphthongs are unlike vowels in that they cannot be adequately characterized by a single vocal tract shape or a single formant pattern. Diphthongs are dynamic sounds in which the articulatory shape slowly changes during their production. Diphthongs and glides are associated with a gradually changing formant structure. The acoustic theory developed earlier for vowels applies in general form to any given configuration in the dynamic complex. For example, the diphthong /ai/ involves a series of vocal tract configurations running from the onglide /a/ to the offglide /i/.

The human resonator, namely, the pharyngeal cavity, the oral cavity and the nasal cavity play an important role in the production of speech. The air spaces between the lips, between the teeth and the cheeks and with in the larynx and tracheae are also resonators. The remarkable characteristic of the human vocal resonator is that its shape can be varied. The cavity shapes can be altered by movements of the articulators. Tongue elevation and fronting creates a smaller area in the oral cavity but widens the area in the pharyngeal cavity. Conversely, tongue depression and backing enlarge the area in the oral cavity while reducing the pharyngeal area. Lip protrusion lengthens the vocal tract creating a lower frequency resonance. The vocal tract is always a resonator and often a source of speech sounds as well.

The posterior part of the vocal tract is formed by a tube of muscles known as the pharynx. The muscles are divided into three groups according to their position - the inferior constrictor, the middle constrictor and the superior constrictor muscles. Contraction of these muscles narrows the pharyngeal cavity and relaxation of the muscle widens it.

The oral cavity is bounded in front and along the sides by the teeth set into the alveolar processes of the upper jaw or maxillary bone and the lower jaw or mandible. The two central incisors and two lateral incisors in each jaw with the use of lower lip, with the tongue and with each other create a constriction for such sounds as /f/, // and /s/. The roof of the oral cavity consists of hard palate and the soft palate. An important landmark on the hard palate is the posterior portion of the alveolar process called the alveolar ridge. Many speech sounds are either generated or resonated as a result of actions of the tongue in relation to the superior alveolar ridge.

The soft palate consists of a broad muscle entering the sides of the velum from the temporal bones behind and above on each side. When these muscles i.e., the levator palatine muscles contract, the soft palate is lifted up and back . toward the posterior wall of the pharynx. This action occurs to some degree for most of the speech sounds except /m/, /n/ and /»)/, where the port to the nasal cavities is left open by relaxing the levator palatini muscles.

Among the various articulators within the oral cavity, the tongue plays an important role in articulation, control of secretions, formation of a bolus, propulsion of bolus toward the pharyx, cleaning the palate and initiation of swallow reflex. (Goday 1991).

The importance of tongue in speech is clearly indicated in the very terra language, which comes from lingua, the Latin word for tongue. Goldberg (1939) notes that language means tonguing, or wagging of the tongue, attributable to the observation of remote ancestors, who by figure of speech, chose the tongue as the chief representative of all of the organs of speech (Travis, 1971) .

The tongue is crucial to speech production because it is the prime determinant of vocal tract shape. It literally alters the entire vocal tract shape when it moves. As an articulator, the tongue's major functions are to,

1. Modulate air flow, and
2. Alter vocal tract shape and thus control resonance frequencies.

Careful inspection of tongue movements during speech suggests that the various parts of the tongue can function semi-independently. (Zemlin 1988).

TONGUE TIP AND BLADE:

By completely stopping the air through pressure of the tip of the tongue against the gum ridge, at the back of the front teeth and by following the stoppage with sudden seperation of the parts, the tongue is an active agent is articulating /t/ and /d/.

By identical stoppage without the supplemental velar action, the tongue is the active agent in articulating /n/.

By pressure of the tip against the center of the gum ridge without contact with the sides so that air escape freely bilaterally, the tongue articulates, /1/.

By light, widely distributed pressure against the hard palate, the tongue interferes with the breath stream so as to produce the requisite friction for / / and *fy/.*

Be elevating the tip or the blade toward the gum ridge so as to direct a constricted, compressed breath stream against the hard palate and thence down against the cutting edges of the lower teeth, the tongue becomes the most active member in articulating /s/ and /z/.

By elevating the tip or blade toward the hard palate behind the gum ridge, the sides being in contact with the inner surface of the upper molars, the tongue interfere with the breath stream so as to constrict it in the manner requisite for /r/.

By pointing downward against the back of the upper teeth so as to interfere with the breath stream and produce the requisite friction, the tongue articulate voiceless // and voiced AS/.

BACK OF THE TONGUE:

By making a complete stoppage of the breath stream through pressure against the velum, which is turn presses against the posterior pharyngeal wall so as to block the nares, and by sudden seperation for the velum while the latter continues to block the nares the back of the tongue becomes the most active member is articulating /k/ and /g/.

Similarly by forming complete occlusion with the velum so as to block the mouth passage, the velum remaining down, the back of the tongue supplements the velum in producing /*1 /.

Hence, the tongue is the most important speech articulator. However, Froeschels (1933), Green (1937) have stated that the tongue is not essential for speech, and that congenital absence or adventitious loss of the tongue need not prevent a victim of such loss from learing to talk. Despite this claim, the tongue is extremely important, it is due to the adept action of the tongue that most of the compensatory movements of speech are achieved by those patients whose oral deformities preclude the development of normal articulatory movements (Travis 1971).

ANATOMY OF THE TONGUE:

The tongue can be divided into four functional subdivisions: Tip, blade, dorsum and root. The apex or the tip of the tongue rests against the lingual surface of the teeth. The blade of the tongue is the anterior most portion of the dorsum, that part of the dorsum just below the alveolar ridge when the tongue is at rest. The remainder of the dorsum may be divided into a front or oral dorsum, lying in front of the faucial pillars, and a back or pharyngeal dorsum, lying behind the faucial pillars. The tongue root, constitutes the fourth division of the tongue. (Zemlin, 1988).

MUSCULATURE OF TONGUE:

Tongue musculature can be divided into,

a. The intrinsic tongue muscles.

b. The extrinsic tongue muscles.

a) The intrinsic muscles of the tongue:

The intrinsic muscles of the tongue have their point of origin and attachment entirely within the tongue proper.

Their primary role is to change the shape of the tongue mass, and to a lesser degree, to alter tongue position. They are also responsible for lifting and curling the tip or edges, and for the bowing or flattening of the body. The origin, insertion and course of the various intrinsic muscles are shown in the figure 7.

The intrinsic muscles are as follows:

1. Vertical muscles -> Fiber originate from the upper surface of the tongue dorsum and run vertically downward to insert into the inferior - lateral surface of the anterior portion of the tongue. Upon contraction this muscle flattens the tongue.

This muscle is innervated by the Hypoglossal nerve (XII CN).

2. Superior longitudinal -> Fibres originate at the base of the tongue and course forward toward the tip, just beneath the mucosal surface of the dorsum. Upon contraction, the muscle tends to shorten the tongue and thereby turn the tip upwards. This muscle is innervated by the XII cranial nerve.

3. Inferior longitudinal -> Fibres run from the base of the apex of the tongue along its undersurf ace. Upon

contraction this muscle either shortens the tongue or pulls the tip downward. Innervated by XII cranial nerve.

4. Transverse muscles -> Fibres run laterally from one side of the tongue to the other, between the two longitudinal muscles. It inserts into two longitudinal muscles. It inserts into the mucosa of the sides of the tongue and into the lingual septum, a layer of connective tissue that runs down the midline of the tongue. Contraction of this muscle causes the tongue to narrow and to become elongated.

B. THE EXTRINSIC MUSCLES OF THE TONGUE:

The extrinsic tongue muscles have one point of attachment within and another outside the tongue. The major function of these muscle is to move the tongue about in the vocal tract in front-to-back and up-and-down directions. The origin, insertion and course of extrinsic muscles are shown in the figure 8.

The extrinsic muscles are as follows:

1. **THE GENIOGLOSSUS** -> Largest muscle of the tongue. It originates near the midline of the lingual surface of the mandible in the region of the superior (mental) spines. One bundle of fibres courses upward to insert into the

Figure 7 : The intrinsic muscles of the tongue.

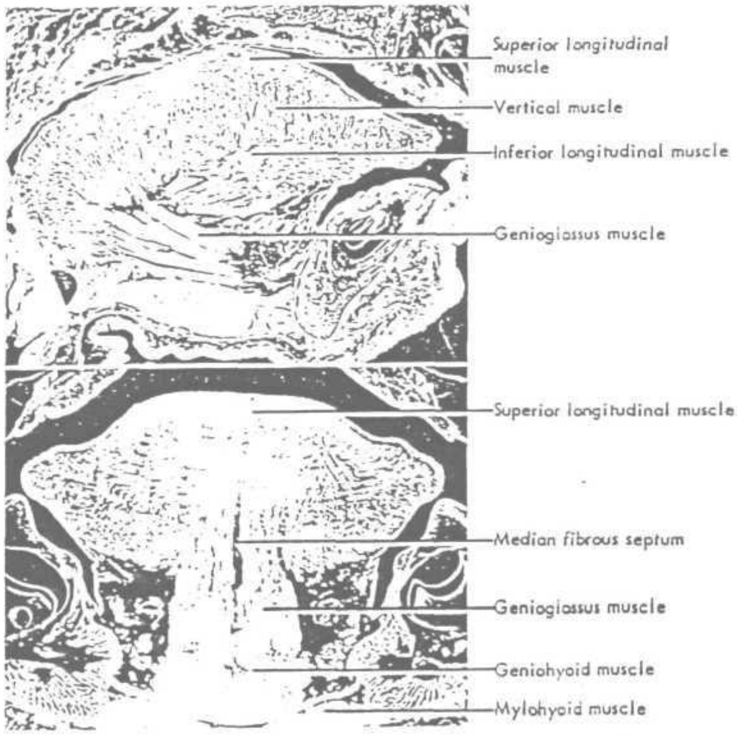
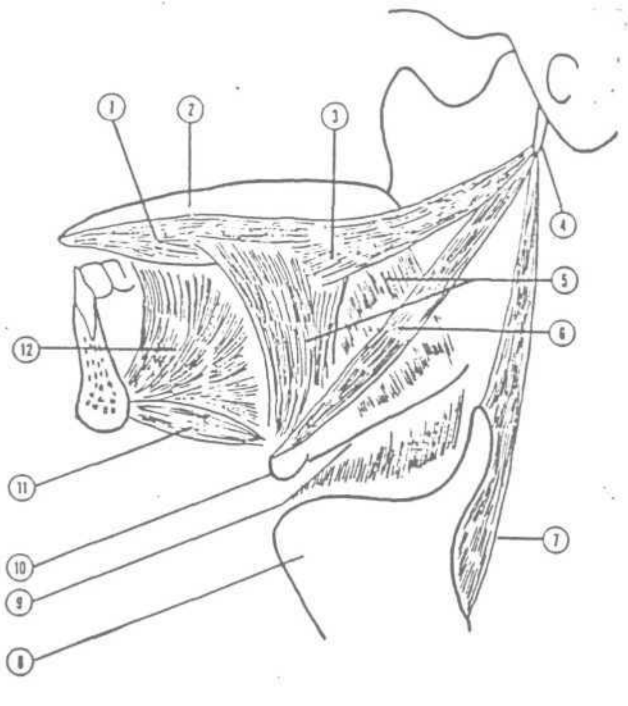


Figure 8 : The extrinsic muscles of the tongue.



1. Inferior longitudinal
2. Dorsum of tongue
3. Styloglossus
4. Styloid process
5. Hyoglossus
6. Stylohyoid
7. Stylopharyngeus
8. Thyroid cartilage
9. Greater cornu
10. .Hyoid bone
11. Geniohyoid
12. Genioglossus

tongue tip. A medial bundle passes rearward and upward to insert along the dorsum. An inferior bundle penetrates rearward and downward to attach to the root of the tongue and to the body of the hyoid bone.

Contraction of the posterior fibres draw the whole of the tongue anteriorly to protrude the tip from the mouth, or to press the tip against the teeth and alveolor ridges. Contraction of anterior fibres is responsible for retraction of the tongue, while contraction of the entire muscle draws the tongue downward, thus making the dorsum like a trough. Innervated by hypoglossal. (XII) nerve.

2. THE STYLOGLOSSUS -> Arises from the styloid process of the temporal bone. It courses down and forward, entering the sides of the tongue and blending with inferior longitudinal and hyoglossus muscles.

Upon contraction the styloglossus draws the tongue upward and backward. It may also draw the sides of the tongue upward. Innervated by XII cranial nerve.

3. THE PALATOGLOSSUS -> Extends from an insertion on the sides of the tongue upward along the wall of the oral cavity. It inserts into the palatal aponeurosis. Upon

contraction it may either lower the soft palate or raise the back of the tongue to groove the dorsum.

4. **THE HYOGLOSSUS ->** A thin sheet of muscle that arises from the upper edges of the greater horn of the hyoid bone. The fibres run vertically and anteriorly, inserting into the body of the tongue and the medial fibrous septum. Upon contraction this muscle depresses and retracts the tongue and elevates the hyoid bone. Innervated by XII cranial nerve.

5. **THE GENIOHYOID ->** Arises from the inferior mental spine of the posterior surface of the mental symphysis of the mandible and courses inferiorly and rearward to insert on the anterior surface of the corpus of the hyoid bone. With the mandible in a fixed position, the geniohyoid muscle pulls the hyoid bone up and forward.

6. **THE MYLOHYOID ->** A sheet of muscle fiber that forms the floor of mouth. Fibres arising from the entire rim of the inner surface of mandible course backward to insert upon a central tendon attached to the hyoid.

With the mandible fixed, contraction of this muscle elevates the hyoid bone, the floor of the mouth, and the tongue. This muscle is an important contributor to the initial stages of deglutition. With the hyoid bone in fixed position, it may assist in depressing the mandible.

Tongue has an important role in the production of vowels, where as, all consonants do not need the participation of the tongue. Those sounds that are produced without involving the tongue movement are the single "nasal" sound /m/, the labial sounds /p,b/, the dental sounds /f,v/ and the pharyngeal sounds /h,?/. All other sounds require the participation of the tongue i.e., /t, d, s, z, g, J , -%,, k, 1, r, j, i, I, e, € ,2e,a,O,o, u, U,A,a'^'^"e[1], y, n/. (Kent 1995) .

The tongue musculatures involved in various vowel production and consonant production are given in Table 2 and Table 3, respectively.

TABLE 2: TONGUE MUSCULATURE INVOLVED IN VOWEL SOUND PRODUCTION.

SOUND	ACTION OF THE TONGUE	MUSCULATURE
/i/	A. strong depression of tongue apex	1. Longitudinal inferior. 2. Genioglossus. 3. Hyoglossus
	B. Strong elevation of posterior tongue dorsum	1. Palatoglossus 2. Styloglossus
/I/	A. Slight depression of tongue apex	1. Longitudinal inferior 2. Genioglossus 3. Hyoglossus
	B. Slight elevation of posterior tongue	1. Palatoglossus 2. Styloglossus
/e/	A. Moderate depression of tongue apex	1. Longitudinal inferior 2. Genioglossus 3. Hyoglossus
	B. Slight elevation of posterior tongue dorsum	1. Palato glossus 2. Styglossus.
/E/	A. Slight elevation of posterior tongue	1. Palatoglossus 2. Styloglossus
/&	B. Strong depression of anterior tongue dorsum	1. Genioglossus 2. Hyoglossus

/a/	A. Moderate depression of anterior tongue dorsum	1. Genioglossus
		2. Hyoglossus
/O/	A. Slight tongue apex depression	1. Genioglossus
		2. Longitudinal inferior
		3. Hyoglossus
	B. Slight depression of anterior tongue dorsum	1. Hyoglossus
		2. Genioglossus
/o/	A. Tongue dossum depression	1. Genioglossus
		2. Hyoglussus
/U/ /u/ /a/ /A/	A. Depresion of Anterior Tongue dorsum	1. Genioglossus
		2 Hyoglussus
	A. Tongue border elevation	1. Palatoglossus
		2. Styloglussus
		3. Transverse lingual

TABLE 3: TONGUE MUSCULATURE INVOLVED IN CONSONANT SOUND PRODUCTION.

SOUND	ACTION	MUSCULATURE
/t//d/	A. Elevation of tongue tip and lateral margins	1. Superior longitudinal 2. Styloglossus
/k//g/	A. Elevation of tongue middle from border to border	1. Palatoglossus 2. Styloglossus
/s//z/	A. Extension of tongue apex	1. Genioglossus
	B. Narrow grooving of tongue dorsum	1. Transverse lingual
/n/	A. Strong elevation of tongue apex	1. Longitudinal lingual superior. 2. Styloglossus
	B. Strong elevation of tongue Middle	1. Palato glossus 2. Styloglossus.
/t;//dj,/	A. Elevation of tongue tip, lateral margins, and central apical regions.	1. Superior longitudinal lingual. 2. Styloglossus
/O//-S/	A. Protrusion of tongue tip	1. Genioglossus 2. Longitudinal superior lingual.

	B. Flattering of tongue dorsums.	1. Vertical tongue muscles
	A. Flattering of tongue dorsums	1. Vertical tongue muscles
	B. Depression of tongue	1. Genioglossus.
	apex	2. Longitudinal inferior lingual
		3. Hyoglossus.
III	A. Elevation of tongue apex	1. Longitudinal superior lingual
		2. Styloglossus
	B. Elevation of tongue borders	1. Transverse lingual
		2. Palatoglossus
Irl	A. Elevation of posterior tongue borders	1. Palatoglossus
		2. Transverse lingual
	B. Depression of tongue	1. Genioglossus
	apex	2. Longitudinal inferior lingual
		3. Hyoglossus
/j/	A. Tongue grooved	1. Transverse lingual
		2. Palatoglossus

Consonants can be classified in terms of, place of articulation and manner of articulation. With respect to place of articulation, all, except the bilabials and labiodentals involve the participation of the tongue. Bilabials such as /p,b,m/ require the lips to come together and labiodentals require the approximation of the lower lip and upper teeth as in /f,v/. All the other sounds such as dentals /6 y ^ /, alveolars /t, d/s,z,n,l,r/, palato-alveolars /t//,/d^/y/^"//^/, palatal / j / and velars /k,g,n,w/ require the participation of the tongue. Hence, absence (congenital, surgical, or traumatic) of the tongue impose serious problems in vegetative and speech functions.

Glossectomy is the surgical removal of part or all of the tongue due to disease, trauma or natural wasting. (Travis, 1971).

Glossectomy may be employed in the surgical treatment of disease, or may occur by accident or as an effect of wasting disease. (Travis 1971).

Total glossectomy for cancer involving 50% or more of the tongue has been slow to gain wide acceptance in the treatment of this disease because of the commonly accepted, potentially grim post-operative outlook. The operative approach is the only method of treatment with an appreciable 3 year survival rate. (Donaldson et al, 1968).

Curative cancer surgery requires that the surgeon remove not only the primary lesion but also the area to which cancer is most likely to spread. Wide margins of normal tissue must also be excised. Tissue to be removed will include lymph nodes of the neck, platysma, sterno cleido mastoid muscle, internal jugular vein, omohyoid muscle, anterior and posterior bellies of the digastric muscle, stylohyoid muscle, submaxillary salivary gland, tail of the parotid gland, all branches of the external carotid artery except the superior thyroid, one-half of the mandible, the entire tongue and if needed, the epiglottis, hyoid bone, and even occassionally the larynx.

Nerves severed will include the accessory, ansa hypoglossi, cervical sensory, mandibular branch of the facial and the hypoglossal. Every effort is made to preserve the vagus, superior laryngeal, cervical sympathetic and phrenic nerves and the brachial plexus. Other structures to be preserved are the common and internal carotid arteries.

Rehabilitation of the glossectomy patient is one of the most difficult and challenging problems for the prosthodontist and speech pathologist.

STUDIES ON VEGETATIVE FUNCTION IN GLOSSECTOMEES

The tongue is the "primary mobile agent" involved during the oral and pharyngeal stages of deglutition and it is the principle articulator during speech. (Robbins 1985).

Safe swallowing requires precise coordination between the oral and pharyngeal phases of swallowing. The passage of an oral bolus without aspiration is the result of a complex interaction of the cranial nerves and muscles of the oral cavity, pharynx and proximal esophagus. (Miller 1982: Morrell 1984:).

Control of bolus in the oral cavity is aided by placement of the tip of the tongue against the maxillary alveolar ridge or superior incisors. The anterior portion of the tongue forms a cup-shape to hold boluses of large volume (Dodds, 1989: Logemann 1986:).

The tongue functions to manipulate oral contents, positioning the food bolus laterally over the molar for effective mastication. (Kahrilas, Lin, Logeman and Ergun 1993).

Morris (1981) reported satisfactory swallowing in 10 patients who underwent total glossectomy without laryngectomy, with varying degrees of speech intelligibility.

Weber (1991) reviewed 27 patients treated between 1982 and 1989 to determine the oncologic effectiveness of total or near total glossectomy with laryngeal preservation and the possibility of speech and swallow rehabilitation following treatment. Swallowing was achieved initially in 18 patients (67%), while 12 had successful long term deglutition (44%). Oral communication was accomplished in 25 patients (92%). Significant aspiration occurred in 3 patients. In the 18 patients with a palatal prosthesis, speech was considered to be good in 7 patients. The effect of laryngeal suspension on speech guality was unclear.

Pauloski (1993) assessed speech and swollow performance for 11 men and 3 women preoperatively and at 1 & 3 months post operatively. Speech tasks included an audio recording of a brief conversation and of a standard articulation test. Swallowing function was examined using videofluoroscopy. Statistical analysis revealed that patients demonstrated a significant and severe impairment in speech and swallow functioning after surgery, with no recovery of function by 3 months post healing.

Logemann (1993) Examined speech and swollow function in 11 patients who underwent surgical resection of greater than 1 cm of tongue base, tonsil and faucial arch with mandible resected. Pre operatively and 1 & 3 months post -healing, audio recordings were made of a 6 - 7 min conversational speech sample, the sentence version of the Fisher Logemann test of articulation competence was administered and videofluroscopic assessment of oropharyngeal swollow was conducted. Patients exhibited greatest difficulty on stop and fricative consonants and bolus propulsion. Comparison with patients who received anterior tongue and floor of mouth resections and distal flap reconstruction revealed consistently better speech performance by the tonsil/base of tongue patients, although the same phonemes were affected. Swallow function was equally affected in the two groups.

Diz - Dios-P (1994) compared the postsurgical deglutition, oral suction and speech capabilities of 11 patients who had undergone partial glossectomy with that of 20 healthy control subjects. Volume swallowed per second and speech quality were significantly correlated with the area of tongue removed. 3 patients subjected to a second operation to improve the mobility of the residual tongue regained almost normal speech intelligibility.

STUDIES ON ARTICULATION IN GLOSSECTOMEES

Glossectomy can be divided into:

-> Partial glossectomy

-> Total glossectomy

It is generally accepted that intelligibility is impossible when the tongue is completely removed. However, some believe that intelligible speech develops after such surgery as a usual consequence of the passage of time and the exercise of some effort on the part of the patient. The optimistic attitude reflects the experience of those who have dealt with cases of partial excision, while a pessimistic view is taken by those who have attempted rehabilitation of patients with total loss of tongue. (Skelly et al 1973).

The extent of articulatory impairment following glossectomy depends on the amount of tissue lost and its location. Skelly et al (1973) reports that the type and extent tongue section are related to speech clarity inthe partial glossectomy group. Excision of the right or left half of the tongue required fewer speech adaptations than excisions including the entire tip. The phonemes /z/, /n/, and /g/ produced by the partial glossectomy resembled the normal. If any flexible portion of the tongue remained, the partial glossectomees were able to approximate the phoneme /$/ and also /d/ within acceptable phonemic limits. The most deviant sounds for these patients were /r/ and /I/.

A patient with a tipless but rather mobile stump may speak better than another one with a preserved tip that is immobilized at the floor of the mouth by scar formation [Goldstein, 1940].

Brodnitz (1960) reporting on speech after glossectomy, states that "missing sounds are developed gradually by vicarious movements of residual muscle stumps or remaining oral musculature". The lower lip substitutes for missing tongue tip by being elevated behind the upper teeth and in this manner [t] [d] [n] are formed. [g] [k] [n] are articulated as pharyngeal sounds between the tongue residue and the pharyngeal wall.

Bradley (1980) assessed articulation after surgery to the tongue and found that vowel phonemes were the poorest discriminators except [i]. The articulatory score ranged from 63.5 -98.4% with a median of 92.1%.

Deborah (1982) reported that compensatory postures for articulation of the stop consonants were characterized by varying degree of labial protrusion, and retraction, dependent on the vowel context. On spectrographic analysis of [p,b,t,d], no stop burst was present in the spectrogrames of the prevocalic stop consonants. Fl and F2 could not be clearly separated from one another and F3 had low energy that it was not recorded.

An acoustic and articulatory study of the vowels of two highly intelligible total glossectomees was made by Morrish (1984). The frequency of Fl for the vowels [i,e,a,o, u] corresponded to that of normal speakers, but the frequency of F2 was much reduced. On videofluroscopy it was found that compensatory articulation for the total glossectomy was achieved by means of exaggerated use of articulators.

Elizabeth (1988) examined the intelligibility, articulation and acoustic features of the vowels and plosives of a male subject who underwent total glossectomy. According to stringent auditory test, overall the subject was found to be between 58% and 65% comprehensible. On videotape analysis and EMG it was found that the subject made all plosive consonants bilabial with extra lip protrusion to distinguish alveolar from bilabial articulation. Individual plosives were not well recognized. Acoustically the subject displayed a greatly reduced vowel space from normals.

Fletcher (1988) investigated charges in dimensions and patterns of articulation used by 3 speakers to compensate for different amounts of tongue tissue excised during partial glossectomy. It was found that, subject 1 who had 10% of his tongue removed apparently simply shifted the place of linguapalatal contact to take advantage of the surgically created indentation along the border of the tongue. Normal groove dimensions were observed, and as the airstream was channeled through the relocated groove, normal high frequency fricational noise was produced. subject 2, who had 40% of his tongue removed transposed the lingual groove from the alveolar to the midpalatal vault region of the palate. However, the metrical properties of the groove were maintained. Subject 3, with 75% glossectomy was physically incapable of achieving the narrow linguapalatal constriction required for sibilant sound production. He shifted from a lingual to a labial gesture. The dimensions of the sibilant groove were essentially the same as for the linguapalatal groove by the other talkers.

Imai (1992) studied the articulatory function after resection of the tongue and floor of the mouth, where lingua palatal contact patterns and the time course of changes in contacts during utterances of [asa, ata, aja, aca] were measured using EPG. The relations between these data and perceptual scores in 17 glossectomized patients were examined. [t] sounds were most frequently judged to be highly distorted. The results revealed that glossectomized patients often evidenced defective stop sounds.

Michiwaki (1992) investigated postoperative articulation in 18 glossectomized patients. A modification of the Freiburger test for speech audiometry was used as test material. Articulatory function was assessed according to an overall score based on 180 monosyllables. It was found that, the cases of tumor of the tongue and the lateral part of the floor of the mouth had excellent scores in all classes of sounds, and the subjects with tumor of the anterior part of the floor of the mouth had low overall scores.

Post operative articulatory functions of 10 patients who received reconstruction with a recto -abdominal myocutaneous free flap after glossectomy was examined by Ikema-Y (1996). On the basis of resection sites, the cases were divided into an anterior type and a lateral type. The functions were investigated by standardized tests, ie., a questionnaires, the 100 Japanese monosyllable speech intelligibility test and a single word intelligibility test. For the monosyllable speech intelligibility test the mean score in cases of the anterior type was 48% and in those of the lateral type it was 62%. For the single word intelligibility test the mean scores in cases of the anterior type was 75% and in lateral type it was 83%. In anterior type, dental and alveolar sounds were often confused with fricatives and in lateral type, velar sounds were confused with affricates.

STUDIES OF INTELLIGIBILITY IN GLOSSECTOMEES

Eskew and Shepard (1945) report on a 22 year old man in whom clinical examination revealed the absence of the tongue, with no rudimentary structure resembling a tongue. The speech was intelligible and he was able to swallow with little difficulty.

During a 12 month period extending from July, 1967, through June, 1968, 25 glossectomized patients are examined by the speech pathology staff at the veteran's administration hospital audiology and speech pathology service. The speech was characterized by extreme articulatory and phonological distortions. The voices were found to have an extremely low pitch and a very narrow pitch range. A common gutteral quality, confounded by excessive pharyngeal and oral noise, compounded the intelligibility problem.

A study was done to explore the effect of vocal parameter manipulation on certain aspects of the intelligibility of 68 glossectonees, i.e., low frequencies gutteral quality and extraneous noise. It was observed that there was high differences between a glossectomee sonogram and the normal printout in all cases. The glossectomees displayed a tendency to diverge in duration from the time base of the normal speaker. Those with a shorter duration than the normal speaker were among the least intelligible. The first formant frequency band appeared to extend over a wider range for the less intelligible and to decrease in range consistently as intelligibility improved. The second formant was absent in the unintelligible speakers sonograms. The spectrograms of unintelligible and least intelligible speakers, a widely distributed random noise pattern appeared and showed highest intensity at the lower frequencies.

Compensatory articulation patterns on the glossal phonemes were developed in a study of 14 total and 11 partial glossectomees by Skelly (1971). Successful compensations were examined by cineflurography. On admission the partial glossectomees ranged between 6 - 24% intelligibility as measured by CID W - 22 PB word lists and shifted after the therapy sequence to a range of 24 - 46%. The total glossectomees ranged from 0 - 8 % intelligibility on admission, and shifted to a range of 18 - 42% in the program.

Conrad La Riviere (1974) report on the perceptual characteristics of speech following glossectomy before the initiation of any therapy of a 32 year old female who underwent radical glossectoray and partial Pharyngectomy. Two word lists of Rhyme test was used to evaluate the subjects intelligibility. Vowel intelligibility was investigated using a fill - in - the missing vowel construction and finally, 10 sentences were selected as an informal check of overall intelligibility. The results revealed that the control subjects were significantly more intelligible than the glossectomee for all materials except the sentences. Among initial consonants, bilabial [p,b,m] and labio dental [f,v] were highly intelligible and phonemes [r,g] were not intelligible. Overall intelligibility was lower for most of the final consonants. The more extreme vowel positions were mis-identified more frequently and a neutral vowel was perceived instead. Spectrographic measures of vowel formant frequencies showed that formants were shifted to more "neutral" position. The intelligibility of the glossectomees sentence productions was as high as 88.8%.

Conrad La Riviere (1975) report on the speech intelligibility of a glossectomee based on perceptual and acoustic analysis. Results based on perceptual analysis were similar to Conrad La Reviere (1974). On acoustic analysis it was found that the formant structures of the vowels were shifted to more 'neutral' positions, the front vowels were backed, the back vowels were somewhat fronted, the high vowels were lowered and the low vowels were raised. The vowel [a] was the most intelligible of the vowel productions (90%) followed by [u] and [i] which was 51% and 33%

respectively. [3!] was the least intelligible [9%]. Diphthongs had a somewhat higher mean intelligibility (50%) than vowels. Mean durations for [b] & [d] were highly similar to [p] and [t]. It was concluded that phoneme duration contributed to intelligibility and confusibility, especially for stop consonants [p,b,t,d].

Leonard (1982) studied the effects of a prosthetic tongue on vowel intelligibility in a patient with total glossectomy. On vowel rhyme test the vowel intellibility improved from 48% to 64% with use of the prosthesis. The front vowels appeared better preserved than back and central vowels, in both prosthesis and nonprosthesis conditions.

Antoni (1984) studied the phoniatric disturbances in patients after partial tongue resection for malignant neoplasms. The results indicated that the cases had rhinolalia aperta, along with a disorder in articulation of front and back consonants and vowels /e/ and /i/. The most frequently disturbed consonants were /r,l,s,z,k,g,h,t,d,&,n/. The articulation of speech sounds was unclear, blurred and inaccurate. The rapidity of the utterance of the isolated syllables was slower. There was slowing down of the rate and blurring of the articulation of the speech sounds in spontaneous speech and reading. The acceleration of the speech rate decreased its intelligibility.

Speech production following partial glossectomy was studied by Samuel (1988). He reported that 15 - 30% of words and 40 - 50% of individual sounds were intelligible. Across the palatometric measures of the CVC words, it was found that greatest contact occurred during production of [t] followed by [/] [s] [z] and [k].

Michi (1989) investigated the speech intelligibility of 4 glossectomy patients before and after a secondary operation in which a split skin graft was used to mobilize the residual tongue. In each case, the post operative speech intelligibility scores were higher than pre operative ones. Sounds produced with the rear portion of the tongue were improved in 3 cases, and plosive and affricative sounds were improved in all cases. This is due to the increased mobility, especially the mid and rear portions of the tongue.

Imai (1988), Michiwaki (1990) reported that speech intelligibility was highest among glossectomized patients for whom reconstruction involved a forearm flap, especially in stop sounds and sounds produced with the rear portion of the tongue such as [k,g].

Studies on speech characteristic of the glossectomees are very few in Western languages and this area has not been touched in Indian languages. Hence, the purpose of the present study is to compare the speech of glossectomees (Malayalam speakers) to that of normals. This will help is better understanding of the speech of the glossectomees and ia their rehabilitation.

METHODOLOGY

The present study aimed at comparing the speech of glossectomee and normal on the following parameters at word level, to determine the similarities and differences between the two. The following parameters were studied.

1. ACOUSTIC MEASURES:

a. Formant frequencies (Fl, F 2, F3) for the vowels in the initial position.
b. Bandwidth (Bl, B2, B3) for the vowels in the initial position.
c. Burst frequency for the consonants (p, b, t, d, k, g, t and d) in the initial position.

2. **TEMPORAL MEASURES:**

a. Vowel duration (VD)
b. Closure duration (CD)
c. Voice onset time (VOT)
d. Burst duration (BD)
e. Total word duration (TWD)

3. **ACCEPTABILITY AND INTELLIGIBILITY.**

Subjects:

Two groups of five Malayalam speakers participated in the study. One group comprised of five glossectomized speakers in the age range 44-63 yrs. These subjects had undergone, either partial or total glossectomy. Details of these subjects are provided in Appendix-I.

The other group comprised of five normal speakers matched for age and language with the glossectomized speakers. This group had no speech and hearing impairments, no neurological impairment and no history of any other problem related to speech and hearing.

Speech material:

The test material consisted of twenty six meaningful Malayalam words. The word list is given in Appendix-II. From the word list ten vowels occurring in the initial position and eight consonants occurring in the initial and medial position were selected.

A standard Malayalam passage (Appendix III) was selected to rate the acceptability.

Data Collection:

All the speakers were first familiarized with the material. The words were visually presented one at a time and the subjects were instructed to produce words followed by a carrier phrase. A standard Malayalam passage was selected and the subjects were instructed to read the passage at their comfortable rate and loudness. Finally, the subjects were also instructed to take in a deep breath and phonate as long as possible at their comfortable loudness and without any breaks in between.

The speech samples of all the subjects were recorded individually in a sound treated room. Recordings were made on hi-bias metal cassettes, using a professional stereo cassette deck (Ahuja) and a AKG-D222 dynamic cardioid microphone with a flat frequency response from 50-15,000 Hz. The microphone-to-mouth distance was approximately 10 cm for all the subjects. These recordings were used for analysis.

Analysis of the data: The analysis principally involved the following equipment:

1) Tape deck to play the recorded speech samples.
2) Antialiasing filter (LPF having cut-off frequency at 7.5 kHz)
3) A-D/D-A converter (sampling frequency rate of 16kHz, 12 bit).
4) PC with intel Pentium 200 MHz microprocessor
5) Software developed by voice-speech system, Bangalore.
6) Amplifier and speaker.

Procedure used for analysis of different parameters:

The program spectrogram was used to obtain a wide band spectrogram (300Hz filter) display. The recorded speech sample was fed through the interface unit at a sampling rate of 16KHz using the program **"Record"** of VSS software. The digitized samples were used for the analysis. The level indicator of speech interface unit was used to monitor the intensity level of the signal to avoid any distortion while digitizing the signal.

All the parameters were obtained from the analysis of digitized sample of speech.

The digitized samples of the first 16 words from the list were used for the measurement of vowel duration. Closure duration, burst duration and voice onset time (VOT), measured from the display and burst frequency measured by spectrographic analysis. From the second half of the word list formant frequencies and band width for all the vowels were measured by spectrographic analysis. Total word duration was measured for all the twenty six words from the display.

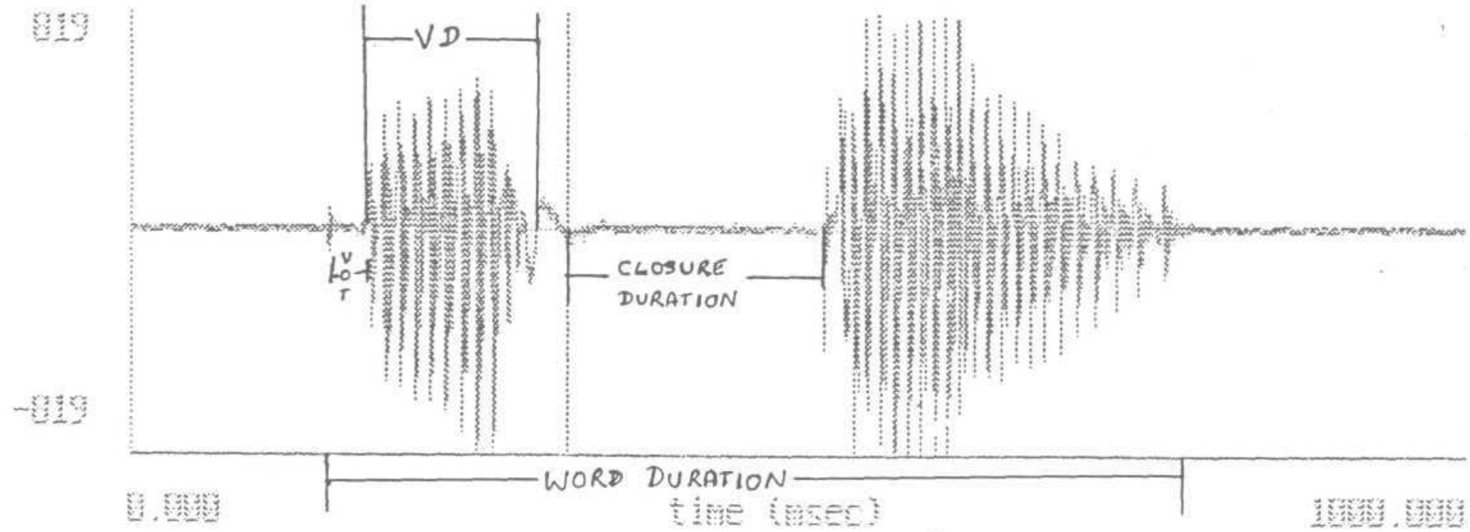
a. BURST DURATION (BD):

The production of a stop consonant involves the complete closure of the vocal tract during which air pressure is built up in the mouth. On the release of the constriction, the air pressure is abruptly released. The acoustic evidence of this release is a burst or transient and the burst duration is no longer than 5-40 msec. It is one of the shortest acoustic events that is commonly analyzed in speech.

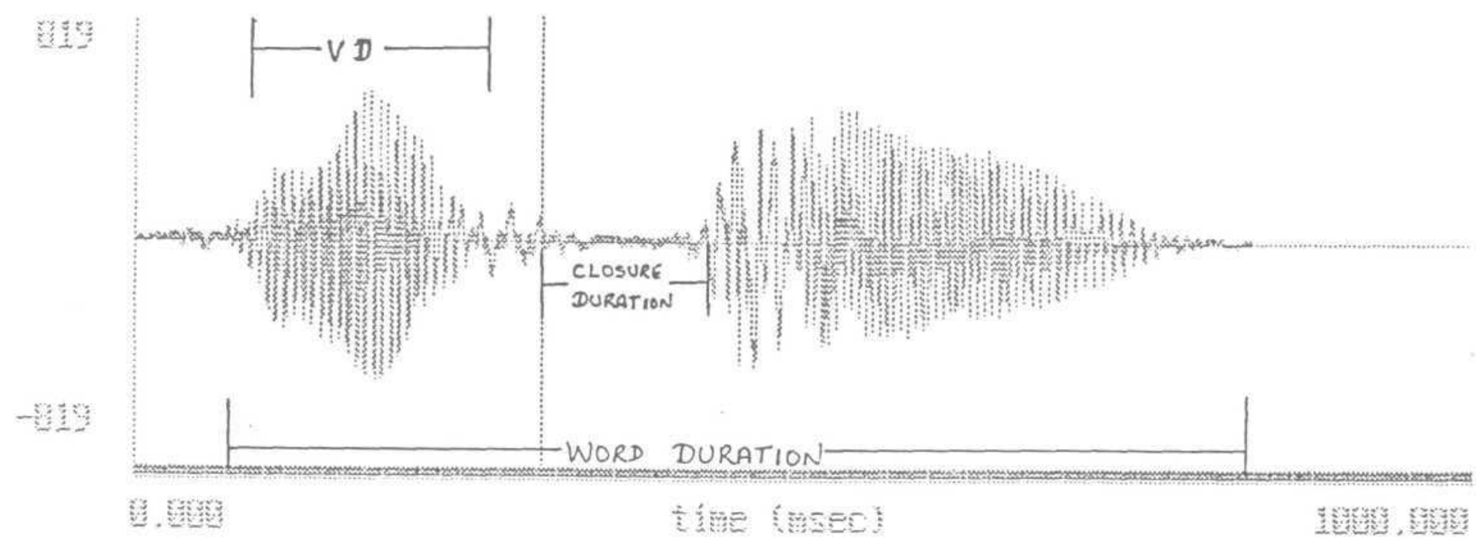
b) VOWEL DURATION:

The vowel duration was measured directly from the speech waveform. The waveform was displayed on the computer monitor using the "DISPLAY" and 'SPGM' programmes of SSL. The vowels were identified based upon the regularity of the waveform and vertical striation. The vowel duration was considered to extend from the end of one periodic portion to the begining of the next a periodic portion. (for vowels in the word medial portion). This duration was highlighted using the cursors. The highlighted portion was played back through headphones, to confirm that it contained the vowel under study. Once this was confirmed, the duration of the highlighted portion was read from the display.

Waveform showing the word '/kʌttil/' as uttered by normal adult.



Waveform showing the word '/kʌttil/' as uttered by glossectomee.



c. **Closure duration:**

The consonant closure duration indicated the time for which the articulator is held in position for stop consonant. Closure duration was the duration between the offset of resonance for the preceding vowel and the onset of burst for the stop consonant in intervocalic condition. The consonant closure duration was determined by placing the cursor at the terminal point of the preceding vowel to that of the onset of burst following it in the spectrogram. The time value thus obtained was the consonant closure duration of that consonant.

d) VOICE ONSET TIME (VOT):

VOT was defined as the time equivalent space from the onset of the stop release burst to the first vertical striiation representing glottal pulsing (Liberman, Delattre and Cooper 1952: Lisker and Abramson, 1964). VOT was measured for the eight consonants in the target word from the wave form and spectrogram using 'SPGM' programme. The cursor was moved to the first indication of energy associated with the stop oral release and the cursor was moved to the begining of the regularly appearing waveform of the vowel following that stop. The real time value (in msec) between these two markings provided the VOT for particular consonants

e). FORMANT FREQUENCIES F1,F2,F3:

To extract the vowel formant frequencies (F1,F2,F3) a spectrogram of each utterance using the "SPGM" program of the software "SSL" was obtained. After identifying the target vowel, the cursor was placed in the middle of the vowel portion so as to avoid the formant transitions, and the formant frequencies were determined by using the sectioning method through the use of linear predictive coding (LPC). This was done with 18 LPC co efficients. The frequencies at the peaks representing the formants were noted using the cursor.

f. **BANDWIDTH:**

To extract the vowel formant bandwidth (B1,B2,B3), a spectrogram of each utterance using the "SPGM" programme of the software SSL was obtained. After identifying the target vowel, the cursor was placed in the middle of the vowel portion so as to avoid the formant transitions, and the bandwidths were obtained by using the "PAT PLAY" of the software SSL.

g. Burst Frequency:

To extract the burst frequency, a spectrogram of each utterance of the target sound, using the "SPGM" programme of the software SSL was obtained. After identifying the burst, the horizontal cursor was placed at the point of the second formant, and thus the burst frequency was obtained.

h. TOTAL WORD DURATION (TWD):

Word duration is the time taken between initiation and termination of a word. It was measured directly from the speech waveform. The waveform was displayed on the computer monitor using the "DISPLAY" programme of SSL. The words were identified based upon the continuity of the waveform. The word duration was considered to extend from the beginning of the periodic signal to the end of the periodic signals. This duration was highlighted through the use of cursors. The highlighted portion was played back through headphones, to confirm that it contained the word under study. Once this was confirmed, the duration of the highlighted portion was read from the display and considered as the duration of that particular word.

i. Acceptability:

Five Speech and Hearing Graduates well versed in Malayalam served as judges. The recorded speech Material of the subjects were played through a tape recorder and the acceptability rated on a 5 point scale (1 being the least acceptable and 5, the most). The judges were not given any specific criteria to rate the acceptability. The judges were instructed to " rate the speech of the samples that you hear, on a five point scale with 1 for the least and 5 for the most acceptable speech". The ratings made by all the five judges were averaged and that was taken as the acceptability score for that subject. Thus the acceptability for the subjects of the two groups was determined.

j. Intelligibility:

Five speech and hearing graduates who were proficient in Malayalam served as judges. The test material read by the normal and glossectomy subjects was played to them randomly 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 levels. A blank may be drawn for the words that are not intelligible to you". The intelligibility score was computed as percentage [(Number of words correctly identified / 26) x 100]. Intelligibility scores provided by all the five judges were averaged.

Thus the following parameters:

a. Formant frequencies

b. Bandwidth

Photograph showing the arrangement of instruments for acoustic analysis.

c. Burst frequency

d. Vowel duration

e. Closure duration

f. Voice onset time

g. Burst duration

h. Total word duration

Were measured for 26 words uttered by each normal and glossectonized subjects.

STATISTICAL ANALYSIS:

Discriptive statistics consisting of mean, standard deviation, minimum and maximum values were obtained for all the parameters analyzed. To check whether there were any significant differences between the values of the normal group and glossectomee group, the T-test was applied. All the statistical analyses were carried using the statistical software package "SPSS".

RESULTS AND DISCUSSION

The objective of the present study was to find out if there was a significant difference between the speech of normals and that of glossectomees.

ACOUSTIC ANALYSIS:

Twenty six Malayalam words uttered by five normal's and five glossectomees were analyzed to obtain the following acoustic parameters.

1. Vowel duration
2. Closure duration
3. Voice onset time
4. Burst duration
5. Burst Frequency
6. Formant frequencies (F1,F2,F3)
7. Bandwidth (B1,B2,B3)
8. Total word duration

The descriptive statistics was obtained for all the measures i.e. the mean and the standard deviation, the minimum and the maximum values were calculated for all the parameters.

1. VOWEL DURATION:

Table 4 provides mean, standard deviation and range of vowel duration in the speech of normal and that of glossectomee subjects Graph 1 provides the mean values of the vowel duration.

On an average, the glossectomy subjects had longer vowel duration when compared to the normal subjects.

The mean vowel duration in normals for /a/,/i/,/u/,/e/ and /o/ were 96.30 msec, 83.82 msec, 117.76 msec, 99.38 msec and 105.02 msec respectively. In glossectomees, the mean vowel duration for /a/, /i/, /u/, /e/, and /o / were 145.18 msec, 184.94 msec, 202.41 msec, 171.51 msec and 172.04 msec respectively.

In normals, the mean vowel duration was shortest for /i/ (83.82 msec) followed by /a/ (96.30 msec), /e/ (99.38 msec), /O / (105.02 msec) and /u/ (117.76 msec). However this trend was not followed in glossectomees, where the shortest vowel duration was found for /a/ (145.18 msec) followed by /e/ (171.51 msec), /o / (172.04 msec), /i/ (184.94 msec) and /u/ (202.41 msec).

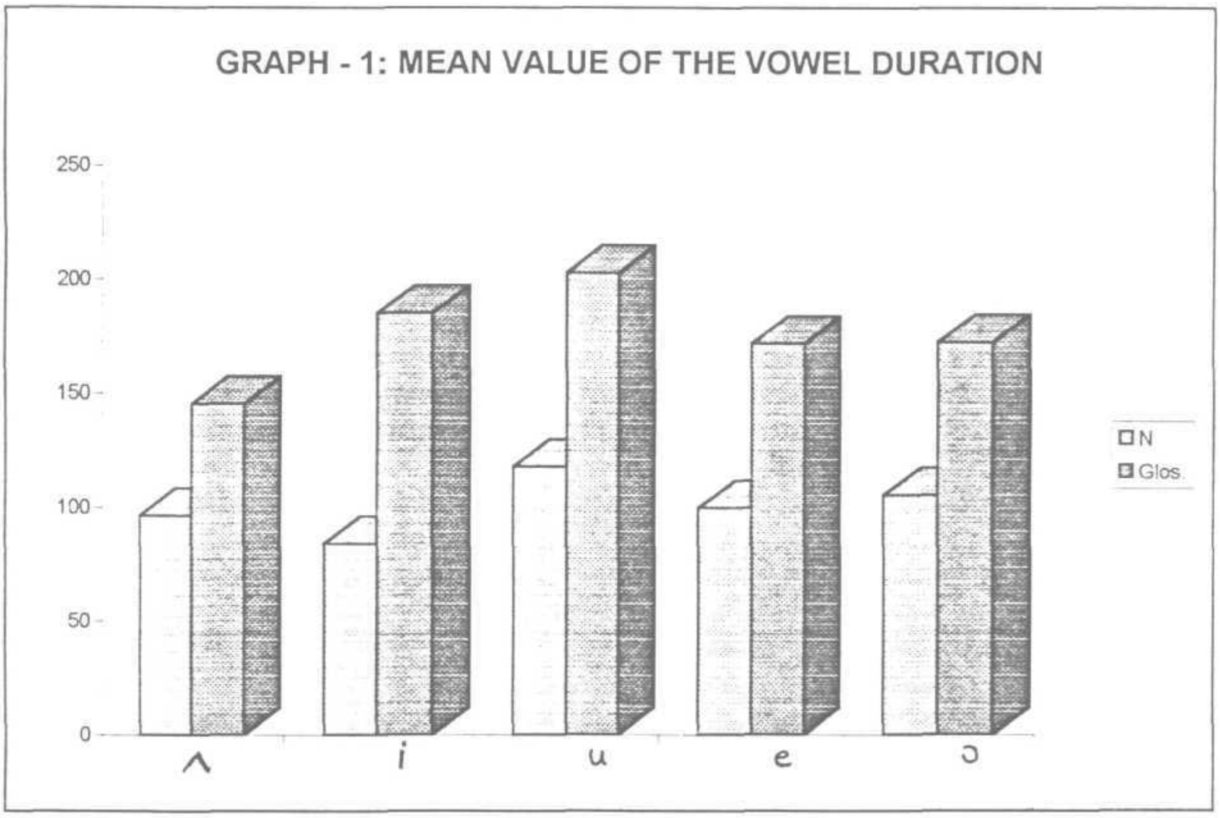
Among both the groups the longest vowel duration was found for /u/ and shortest for /i/ and /a/ in normals and glossectomees.

Table 4: Mean, standard deviation range and mean difference values of vowel duration in the speech of normal's and glossectomees.

	NORMAL			GLOSSECTOMEE			Mean difference
vowels	Mean	SD	Range	Mean	SD	Range	(N & Gloss)
* a	96.30	11.30	86-112(26)	145.18	34.32	94-184.37 (90.37)	-64.37
* i	83.82	15.19	61-103(42)	184.94	42.34	114-221 (107)	-65
* u	117.76	28.37	90-148.4 (58.4)	202.41	66.74	142.18-310.90 (168.72)	-110.32
* e	99.38	7.86	87-107(20)	171.51	35.50	147-231(84)	-64
*J	105.02	6.16	98-113.31 (15.31)	172.04	25.84	137-207.8 (70.80)	-55.49

** Significance difference between the means at 0.05 level.*

72a



GRAPH - 1: MEAN VALUE OF THE VOWEL DURATION
250
200
150
100
50
0
ʌ
i
u
e
ɔ
N
Glos.

On T - test, it was found that there was significant difference in vowel duration for all the five vowels between normals and glossectomees.

Hence, the hypothesis stating that there is no significant difference in vowel duration between the normals and glossectomees was rejected.

2. CLOSURE DURATION:

Table 5 provides mean, standard deviation, and range of closure duration in the speech of normals and glossectomees. Graph 2 provides the mean values of the same.

In general, the closure duration in glossectomy subjects was slightly longer when compared to the normal subjects.

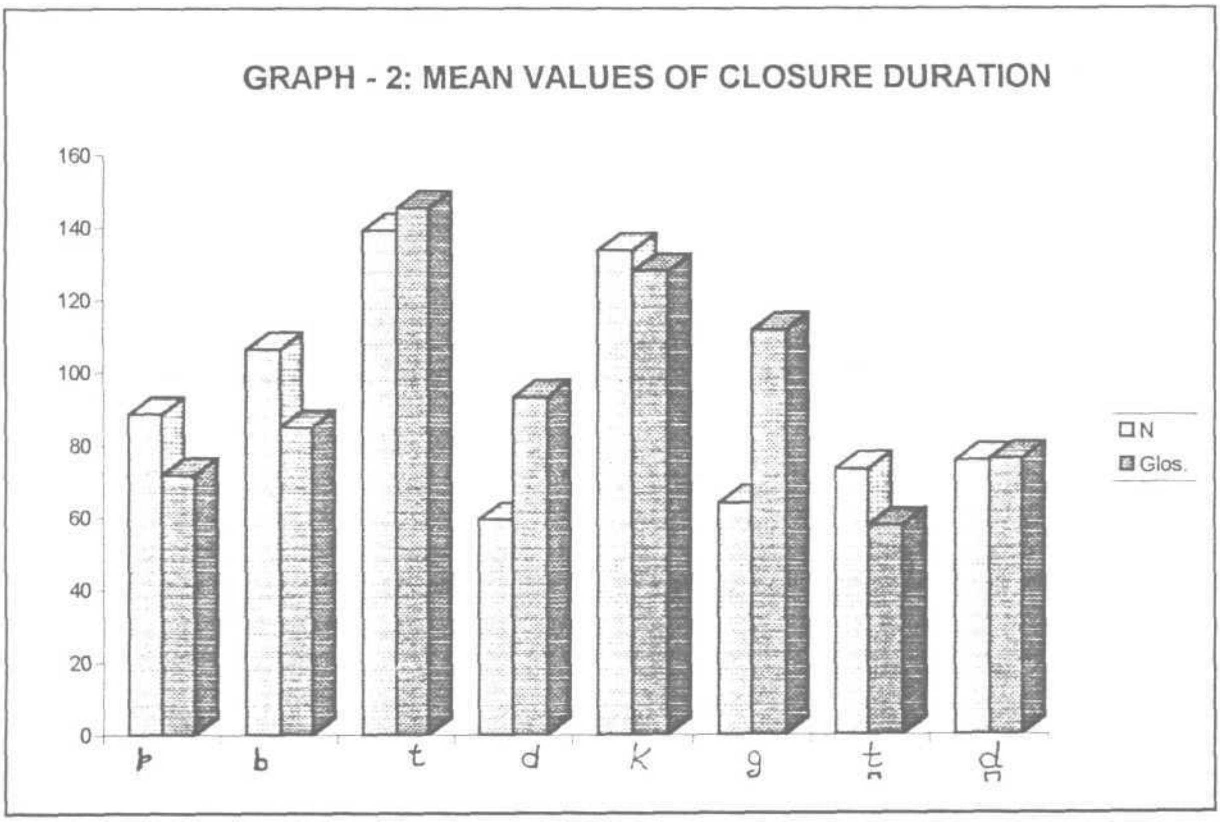
The closure duration for the bilabials /p/ and /b/, voiceless velar /k/ and voiceless dental /t/, was longer in normals when compared to glossectomees. The closure duration for the alveolars /t/ and /d/, voiced velar /g/ and voiced dental /d/ was longer in glossectomees when compared to normals.

The mean closure duration in normals was shortest for /d/ (59.20 msec) followed by /g/ (63.80 msec), /t/ (73.20 msec), /d/ (75.40 msec) /p/ (88.47 msec)./b/ (106.20 msec), /k/ (133.56 msec) and /t/ (139.05 msec).

Table 5: Mean, standard deviation, (SD), range and mean difference values of closure duration in the speech of the normals and glossectomees.

	NORMAL				GLOSSECTOMEE				Mean difference
Sd	N	Mean	SD	Range	N	Mean	SD	Range	(N & Gloss)
p	5	88.47	16.24	68-106(38)	4	71.75	19.46	57-98(41)	+16.72
b	5	106.20	21.05	79-131(52)	3	84.66	19.03	65-103(38)	+21.54
t	5	139.05	49.18	100-225(125)	5	145.31	41.02	89-194(105)	- 6.26
d	5	59.20	17.54	36-77(41)	1	93.00	-	- -	
k	5	133.56	24.49	112-175(63)	5	127.75	52.66	71-184(113)	+ 5.81
g	5	63.80	6.34	60-75(15)	2	111.50	13.43	102-121(19)	-47.7
t	5	73.20	16.39	54-96(42)	4	57.50	5.74	53-65(12)	+15.7
d	5	75.40	15.02	50-90 (40)	3	75.83	11.42	68.6-89(21)	- 0.43

74a


GRAPH - 2: MEAN VALUES OF CLOSURE DURATION
160
140
120
100
80
60
40
20
0
p
b
t
d
k
g
ṯ
ḏ
N
Glos.

In glossectomees, the closure duration was shortest for /t/ (57.50) followed by /p/ (71.75 msec) /d/ (75.83 msec), /b/ (84.66 msec), /d/ (93.00 msec), /g/ (111.50 msec), /k/ (127.75 msec) and /t/ (145.31 msec).

Among both the groups /t/had the longest closure duration.

In normals, the mean closure duration for the voiceless bilabial and dental consonant were shorter than their voiced counter part. That is, the closure duration for /p/ was shorter than /b/ and closure duration for /t/ was shorter than /d/. The closure duration for voiceless alveolar stop and voiceless velar stop were longer than their voiced counterpart. That is, the closure duration for /t/ was longer than /d/ and closure duration for /k/ was longer than /d/ and closure duration for /k/ was longer than /g/. The same trend was seen in glossectomy group also.

On a average, the closure duration range was longer in normal's when compared to glossectomees. The range in normals was 36-225 and 53-194 in glossectomees.

Closure duration was present among all the five normal subjects for all the eight consonants. However, among glossectomees only four subjects showed closure duration for

/p/ and /t/, three for /b/ and /d/, five for /t/ and /k/, one for /d/, and two for /g/.

On statistical analysis it was found that there was no significant difference in closure duration between normals and glossectomees.

Hence, the hypothesis stating there is no significant difference in closure duration between normals and glossectomees is accepted.

3. VOICE ONSET TIME (VOT):

Table 6a, and table 6b provides mean, standard deviation and range of voice onset time for the voiceless and voiced consonants respectively, in the speech of normal's and glossectomees. Graph 3a and 3b provides the mean values of the same.

On an average, the normal's had much longer VOT when compared to glossectomees.

Table 6a: Mean, SD, range and mean difference values of VOT for voiceless consonants in normals and glossectomees.

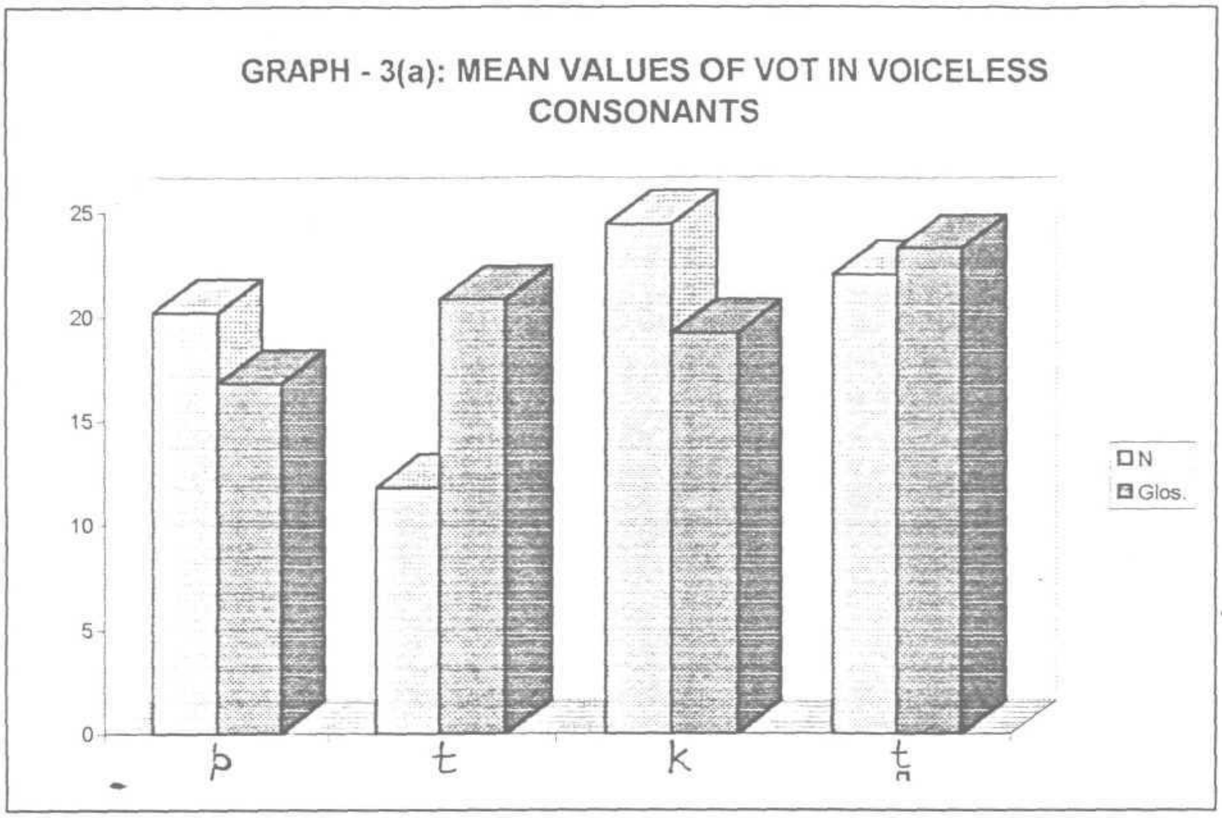
	NORMAL				GLOSSECTOMEE				Mean difference
Sd	N	Mean	SD	Range	N	Mean	SD	Range	(N & Gloss)
p	5	20.20	4.60	15-25 (10)	5	16.80	3.27	12-21(9)	+ 3.4
*t	5	11.80	0.83	11-13 (2)	5	20.82	8.86	12-35(23)	- 9.02
k	5	24.40	8.01	17.37 (20)	5	19.2	6.72	12-30 (18)	+ 5.2
t	5	22.00	2.64	18-25(7)	5	23.25	5.40	19.25-32 (12.75)	-1.25

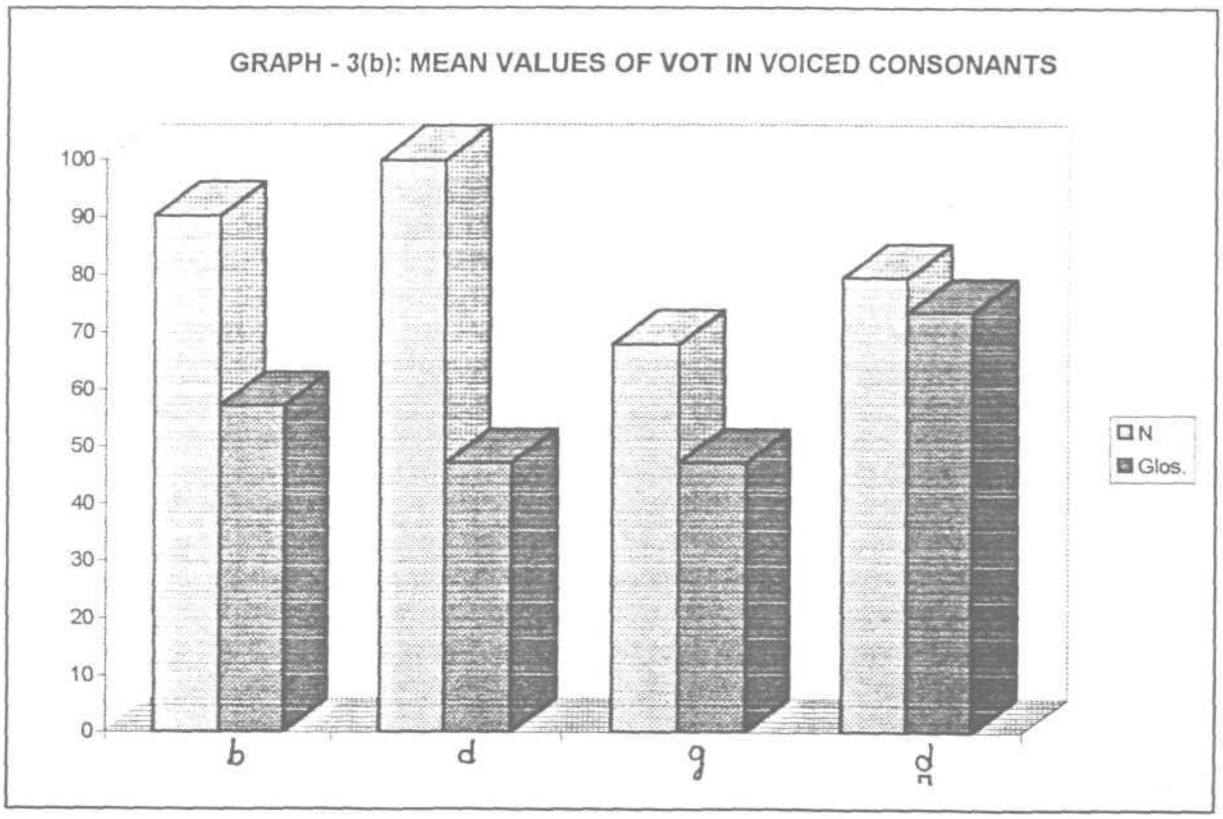
* *Significance difference between the means at 0.05 level.*

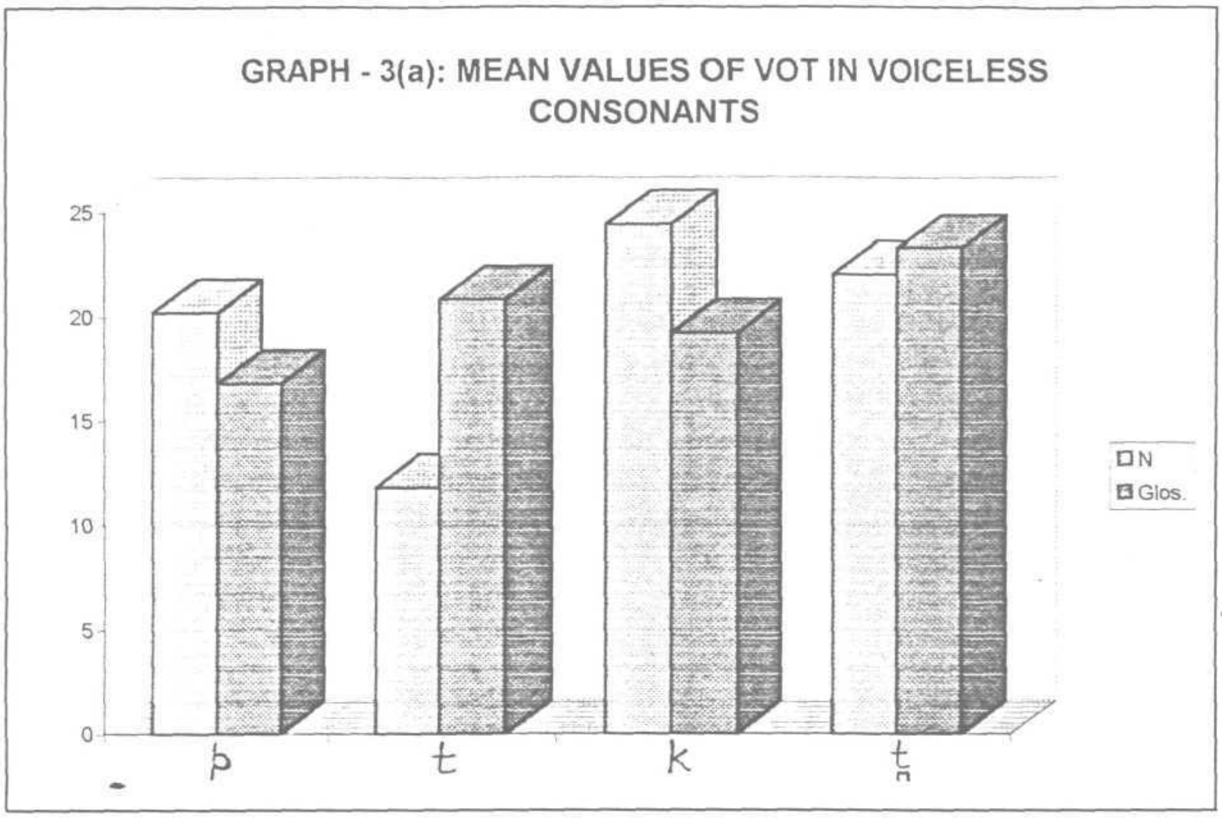
In normals, the mean VOT for the voiceless consonants was shortest for /t/ (11.80 msec), followed by /p/ (20.20 msec), /t/ (22.00 msec), and /k/ (24.40 msec). However, in glossectomees the mean VOT for the voiceless consonants was shortest for /p/ (16.80 msec), followed by /k/ (19.20 msec), /t/(20.82 msec),/t/ (23.25 msec). The mean VOT for the voiced consonants in normals was shortest for /d/ (99.80 msec) followed by /b/ (90.20 msec), /g/ (67.80 msec) and /d/ (79.40 msec). This trend was not seen in glossectomy subjects. The shortest VOT was found for /d/ (73.37 msec) followed by /b/ (57.12 msec), /g/ (47.04 msec) & /d/ (47.0 msec).

The mean VOT in normal's for all the voiceless consonants were much longer when compared to the voiced consonant. The same results were observed in glossectomees also, where the VOT for voiceless consonants were longer than the voiced consonants.

The range for bilabials /p/ and /b/, velars /k/ and /g/ were longer in normals when compared to glossectomees. The range for /p/in normals and glossectomees were 15-25 msec and 12-21 msec respectively. For /b/, normals had a range of 53-121 msec and glossectomees had a range of 30.6-76 msec. For /k/, the range was 17-37 msec in normals and 12-30 msec in glossectomees. The range for /g/ in normals and glossectomees were 40-109 msec and 33-63.7 msec respectively.


GRAPH - 3(a): MEAN VALUES OF VOT IN VOICELESS CONSONANTS
25
20
15
10
5
0
N
Glos.
p
t
k
t̪


GRAPH - 3(b): MEAN VALUES OF VOT IN VOICED CONSONANTS
100
90
80
70
60
50
40
30
20
10
0
N
Glos.
b
d
g
d̪


GRAPH - 3(a): MEAN VALUES OF VOT IN VOICELESS CONSONANTS
25
20
15
10
5
0
p
t
k
t̪
N
Glos.

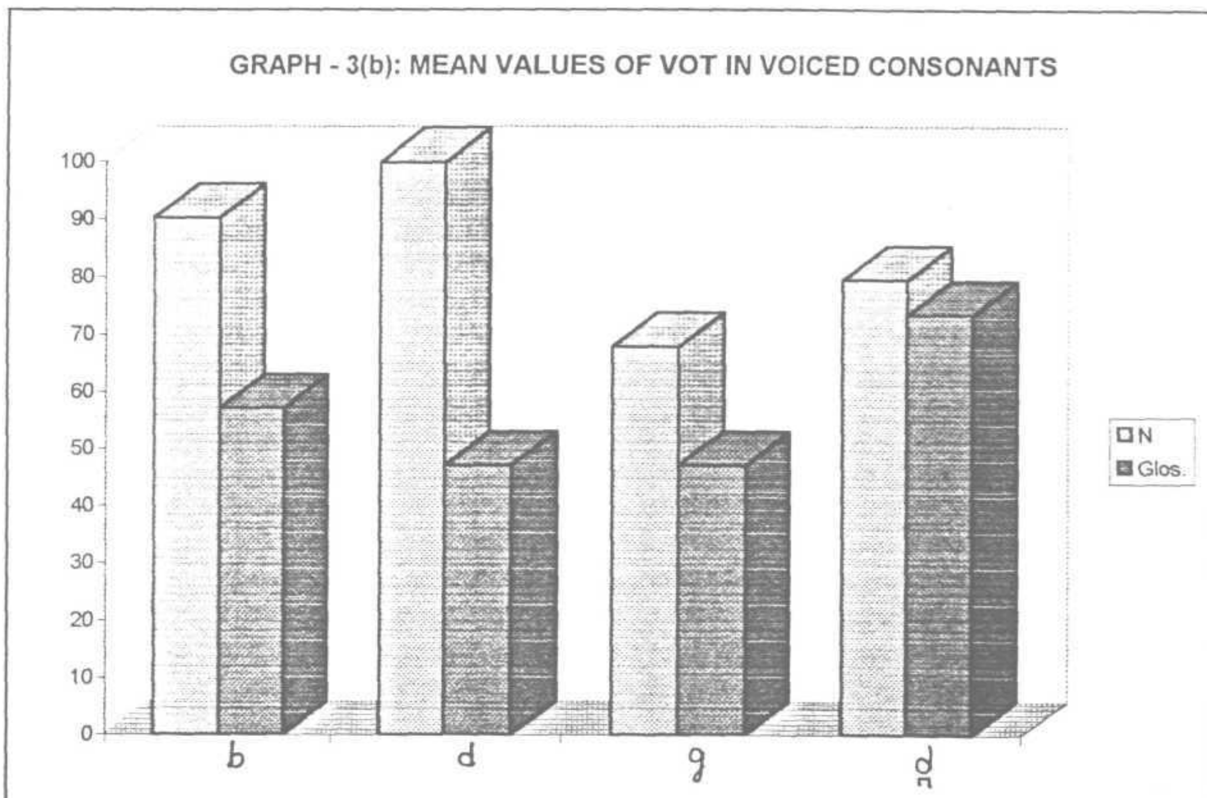

GRAPH - 3(b): MEAN VALUES OF VOT IN VOICED CONSONANTS
100
90
80
70
60
50
40
30
20
10
0
b
d
g
d̪
N
Glos.

Table 6b: Mean, SD, range and mean difference values of VOT for voiced consonants in normals and glossectomees.

	NORMAL				GLOSSECTOMEE				Mean difference
Sd	N	Mean	SD	Range	N	Mean	SD	Range	(N & Gloss)
*b	5	90.20	27.95	53-121 (68)	5	57.12	18.32	36.6-76 (45.4)	+ 33.08
*d	5	99.80	20.46	76-117 (41)	5	47.00	23.90	25-81 (56)	+ 52.8
g	5	67.80	25.64	40-109 (69)	5	47.04	11.55	38-63.7 (30.7)	+ 20.76
d	5	79.40	29.04	53-112 (59)	5	73.37	34.48	42.87-130 (87.13)	+ 6.03

* *Significance difference between the means at 0.05 level.*

The range for alveolars /t/ and /d/, dentals /t/ and /d/ were longer in glossectomees when compared to normals. For /t/, normals had a range of 11-13 msec and glossectomees had a range of 12-35 msec. For /d/, the range in normals and glossectomees were 76-117 msec and 25-81 msec respectively.

The range for /t/ in normals and glossectomees were 18-25 msec and 19.25-32 msec respectively and for /d/, 53-112 msec and 42.87-130 mse in normal and glossectomees respectively.

However, on an average it was observed that the normals had a longer VOT has glossectomees.

Significant difference was found for /b/,/t/ and /d/. No significant difference was observed for /p/, /k/, /g/, /t/ and /d/. However, on group statistics it was found that there was a significant difference among the two groups for VOT.

Hence, the hypothesis, there is no significant difference in VOT between normals and glossectomees is rejected.

4. BURST DURATION:

Table 7 provides mean, standard deviation and range of burst duration in the speech of normals and glossectomees. Graph 4 provides the mean values of the burst duration.

Burst duration was comparatively longer in normal subjects than the glossectomy subjects.

The mean burst duration for normal's and glossectomee's were 6.39 and 5.93 msec respectively.

Burst duration ranged from 4-9 msec in normal's and 4-8.8 msec in glossectomees.

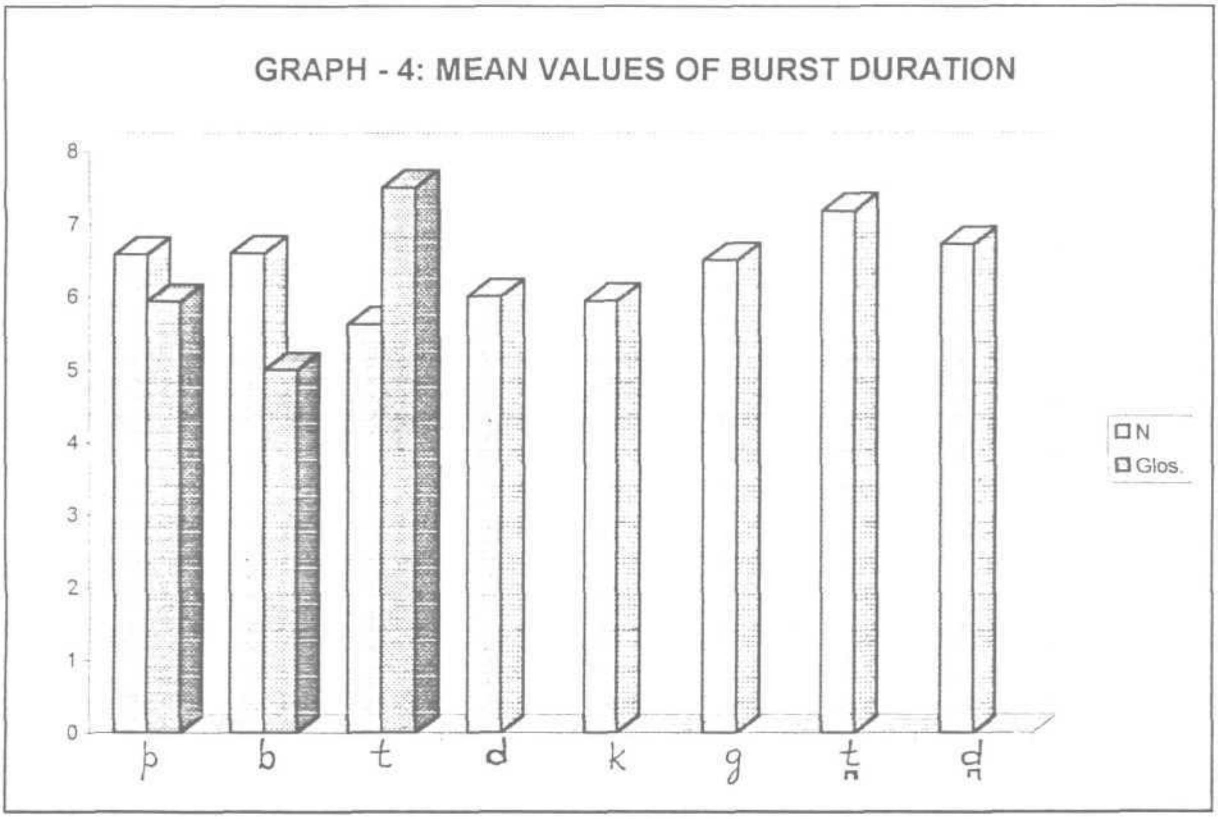
In glossectomees, burst was not observed and hence burst duration could not be measured for /d/,/k/,/g/,/t/ and /d/. Among glossectomees, only three of the subjects presented burst for /p/, two for /b/ and one for /t/. The consonants were either distorted or substituted and hence burst was not observed.

In cases where burst was present, the energy concentration was very much reduced when compared to normals. This may be due to reduced intra-oral pressure.

There was no significant difference for burst duration between normals and glossectomees for /p/, /b/ and /t/.

Table 7: Mean, SD, range and mean difference values of burst duration in the speech of normals and glossectomees.

	NORMAL				GLOSSECTOMEE				Mean difference
Sd	N	MEAN	SO	RANGE	N	MEAN	SO	RANGE	(N & Gloss)
p	5	6.58	1.52	5-9 (4)	3	5.93	2.53	4-8.8 (4.8)	+ 0.65
b	5	6.60	1.50	5.1-9 (3.9)	2	5.0	0.70	4.5-5.5 (1)	+ 1.6
t	5	5.62	1.19	4-7 (3)	1	7.5	-	—	- 1.88
d	5	6.0	0.61	5-6.5 (1.5)	-				
k	5	5.94	1.15	4-7 (3)	-				
g	5	6.50	1.48	5.1-9 (3.9)	-				
t	5	7.18	1.28	6-9 (3)					
d	5	6.72	0.78	5.5-7.6 (2.1)	-				


GRAPH - 4: MEAN VALUES OF BURST DURATION
8
7
6
5
4
3
2
1
0
p
b
t
d
k
g
ṱ
ḓ
N
Glos.

5.BURST FREQUENCY:

Table 8 provides mean, standard deviation and range of burst frequency in the speech of normals and glossectomees.

Graph 5 provides the mean values of the burst frequency.

Burst frequency was much higher in glossectomees when compared to normals. The mean burst frequency for normals and glossectomees were 1659.05 Hz and 1730.30Hz respectively.

Burst frequency ranged from 674-3309 Hz in normals and 1019-2243 Hz in glossectomees.

In glossectomees, burst frequency could be measured only in cases where burst was present. Burst frequency could be measured from three of the glossectomy subjects for /p/, two for /b/ and one for /t/.

The mean burst frequency for /p/ in normals and glossectomees were 862.20 Hz and 1506.6Hz respectively. For /b/, the burst frequency was 1162.60 Hz and 1105.5 Hz in normals and glossectomees respectively. For /t/, mean burst frequency in normals was 1615.2 Hz and in glossectomees, 1853 Hz.

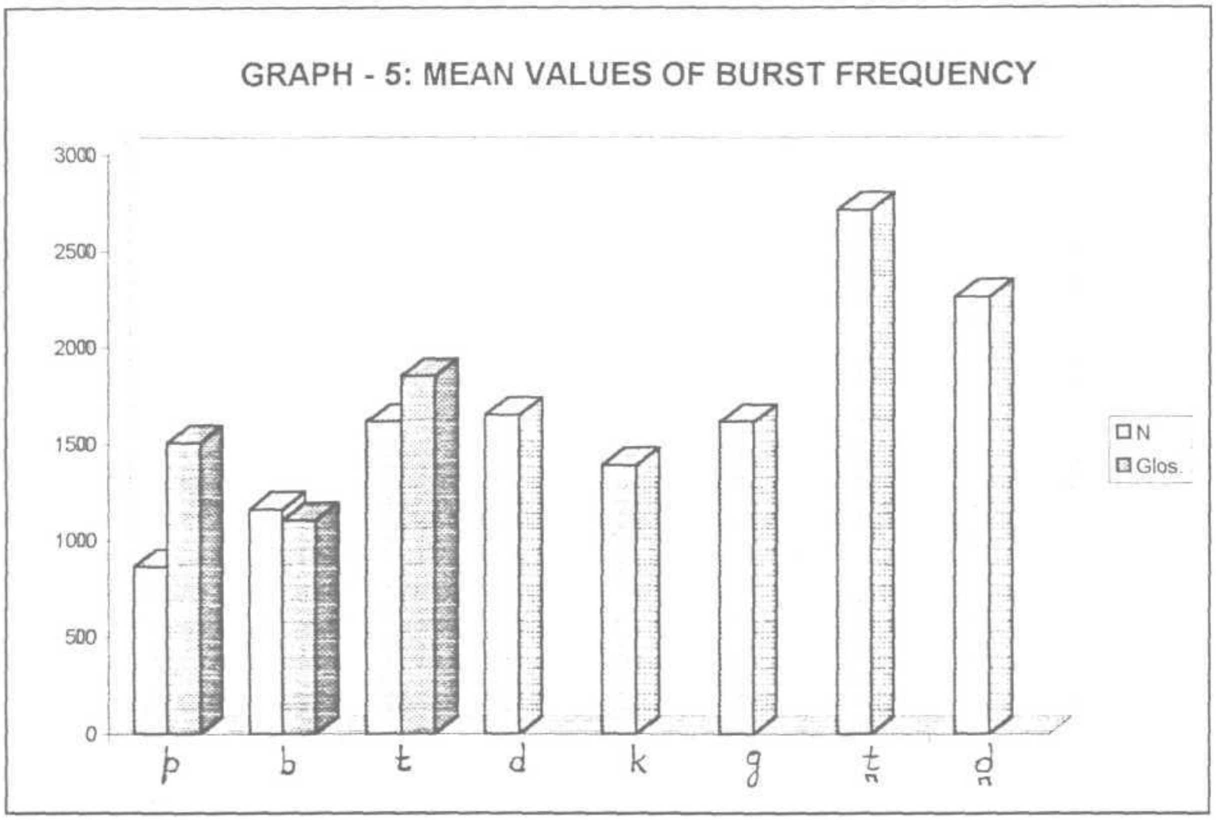
For /d/, /k/, /g/, /t/ and /d/ , burst frequency could not be measured in glossectomees, since the burst was not present. Hence, comparison of burst frequency for these consonants could not be made between normals & glossectomees.

Significant difference was found for /p/ between the two groups. No significant difference was observed for /b/ and /t/. Hence hypothesis stating that there is no significant difference in burst frequency between normal's and glossectomees was accepted from /b/ and /t/ and rejected for /p/.

Table 8: Mean, standard deviation (SD), range and mean difference values of burst frequency in the speech of normals and glossectomees.

	NORMAL				GLOSSECTOMEE				Mean differenc (N & Gloss)
Sd	N	MEAN	SD	RANGE	N	MEAN	SD	RANGE	
*p	5	862.20	134.96	674-988 (314)	3	1506.6	637.92	1121-2243 (1122)	- 644.4
b	5	1162.60	309.14	956-1705 (749)	2	1105.5	122.32	1019-1192 (173)	+ 57.1
t	5	1615.2	125.62	1427-1741 (314)	1	1853	–	–	- 237.8
d	5	1652.8	95.13	1521-1772 (251)	-				
k	5	1389.6	92.26	1302-1521 (219)	-				
g	5	1615.2	209.26	1396-1929 (533)	-				
t	5	2713.2	376.37	2274-3309 (1035)	-				
d	5	2261.6	199.23	2023-2494 (471)	-				

* *Significance difference between the means at 0.05 level.*


GRAPH - 5: MEAN VALUES OF BURST FREQUENCY
3000
2500
2000
1500
1000
500
0
p
b
t
d
k
g
N
Glos.

6. FORMANT FREQUENCY CHARACTERISTICS OF VOWELS:

a. First Formant Frequency:

Table 9a and Table 9b provides mean, standard deviations and range of Fl for short and long vowels respectively in the speech of normal group and glossectomy group.

Graph 6a and graph 6b provide mean values of the same.

In general, the glossectomy group had higher Fl than those of the normal group. The mean Fl values of all short vowels produced by glossectomy subjects were found to be higher than that of the normal subjects expect for /o/ (lower by 23.60 Hz). For /a/ the difference between the means of glossectomees and that of normals was 19 Hz, for /i/ - 67.2 Hz, for /u/ - 13.8 Hz, for /e/ - 33 Hz and for /O/ - 23.6 Hz.

However significant mean difference between the groups was not found for any of the short vowels.

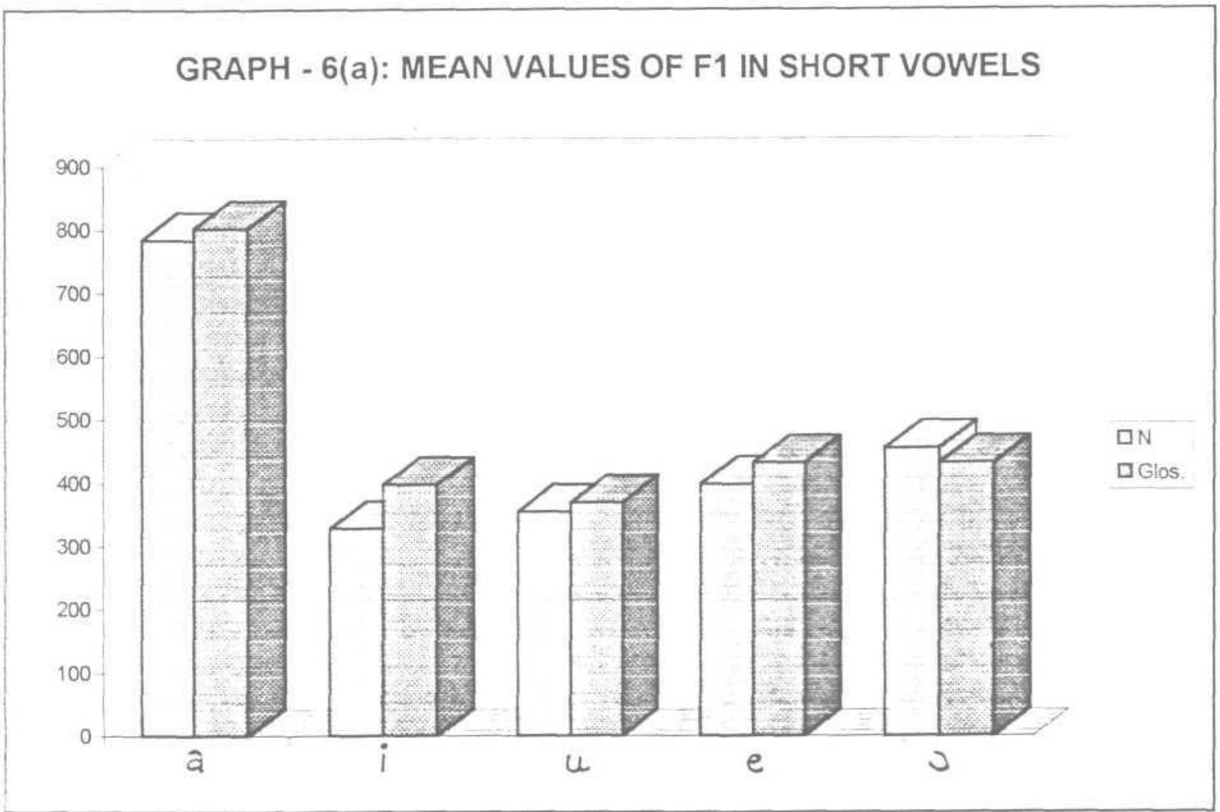
The mean Fl values of all long vowels produced by the glossectomy group was found to be higher than that of normal group except for the vowel /0:/ (lower by 640 Hz). The mean difference between the means of glossectomees to that of normal's for vowels /a:/, /i:/, /u:/, /e:/ &/o:/ were 167.8 Hz, 62.4 Hz, 26.6 Hz, 54.4Hz and 6.4 Hz respectively.

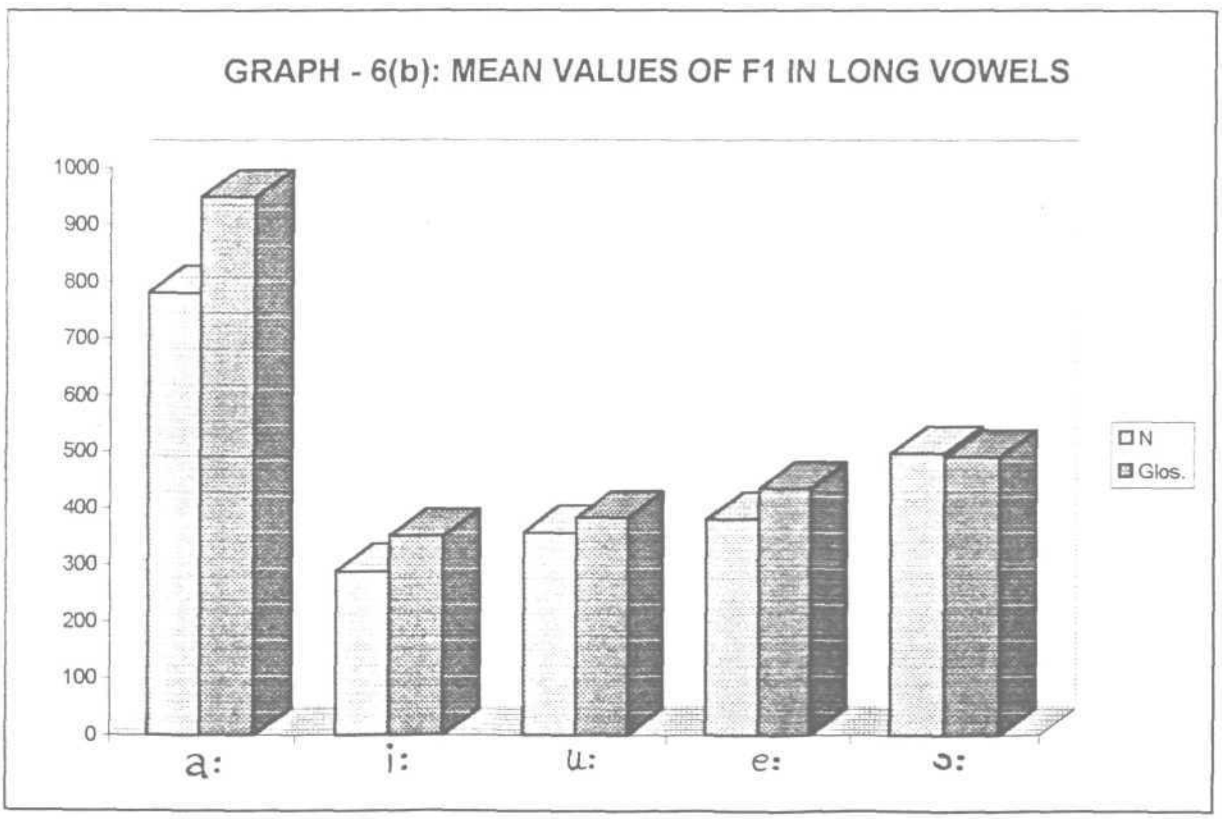
Table 9a: Mean, standard deviation (SD), range and mean difference values of F1 for short vowels in the speech of normals and glossectomees.

V	NORMAL N	MEAN	SD	RANGE	GLOSSECTOMEE N	MEAN	SD	RANGE	Mean differenc (N & Gloss)
a	5	783.80	58.59	737-862 (125)	5	802.8	131.73	651-996 (345)	- 19
i	5	329	31	298-360 (62)	5	396.2	67.06	298-454 (156)	- 67.2
u	5	354.2	34.50	329-392 (63)	5	368	96.64	266-478 (212)	- 13.8
e	5	398	51.73	360-486 (126)	5	431	42.10	392-486 (94)	- 33
o	5	454.4	97.46	313-580 (267)	5	430.8	133.85	235-603 (368)	23.6

Table 9b: Mean, standard deviation (SD), range and mean difference values of FI for long vowels in the speech of normals and glossectomees.

V	NORMAL N	MEAN	SD	RANGE	GLOSSECTOMEE N	MEAN	SD	RANGE	Mean differenc (N & Gloss)
a:	5	780.80	72.25	674-831 (157)	5	948.6	221.91	729-1270 (541)	- 167.8
i:	5	288.4	30.55	251-329 (78)	5	350.8	69.46	274-462 (188)	- 62.4
u:	5	355.6	55.69	321-454 (133)	5	382.2	97.48	243-494 (251)	- 26.6
e:	5	379.8	63.04	329-490 (161)	5	434.2	72.09	345-525 (180)	- 54.4
o:	5	496.8	101.38	376-643 (267)	5	490.4	92.64	423-603 (180)	+ 6.4


GRAPH - 6(a): MEAN VALUES OF F1 IN SHORT VOWELS
900
800
700
600
500
400
300
200
100
0
a
i
u
e
ɔ
N
Glos.


GRAPH - 6(b): MEAN VALUES OF F1 IN LONG VOWELS
1000
900
800
700
600
500
400
300
200
100
0
a:
i:
u:
e:
ɔ:
N
Glos.

However no significant mean difference was found for any of the long vowels.

The hypothesis stating that there is no significant different between the means of Fl values of glossectomees and normals was accepted for all the vowels.

(b) Second Formant Frequency:

Table 10a and table 10b provide mean, standard deviation and range of F2 for short and long vowels respectively in the speech of the glosssectomy and normal groups. Graph 7a and graph 7b provide mean values of the same.

The mean F2 values of all short vowels produced by the glossectomy group was found to be higher than that of normal group except for vowels /i/ and /e/ which was lower by 273.4 Hz and 280.8 Hz respectively. The difference in mean F2 between the two groups for vowels /a/, /i/, /u/, /e/ and /o/ were 298 Hz 273.4 Hz, 302.8 Hz, 280.8 Hz and 541.2 Hz respectively.

Significant difference was found for all the short vowels.

Table 10a: Mean, standard deviation (SD), range and mean difference values of F2 for short vowels in the speech of the normals and glossectomees.

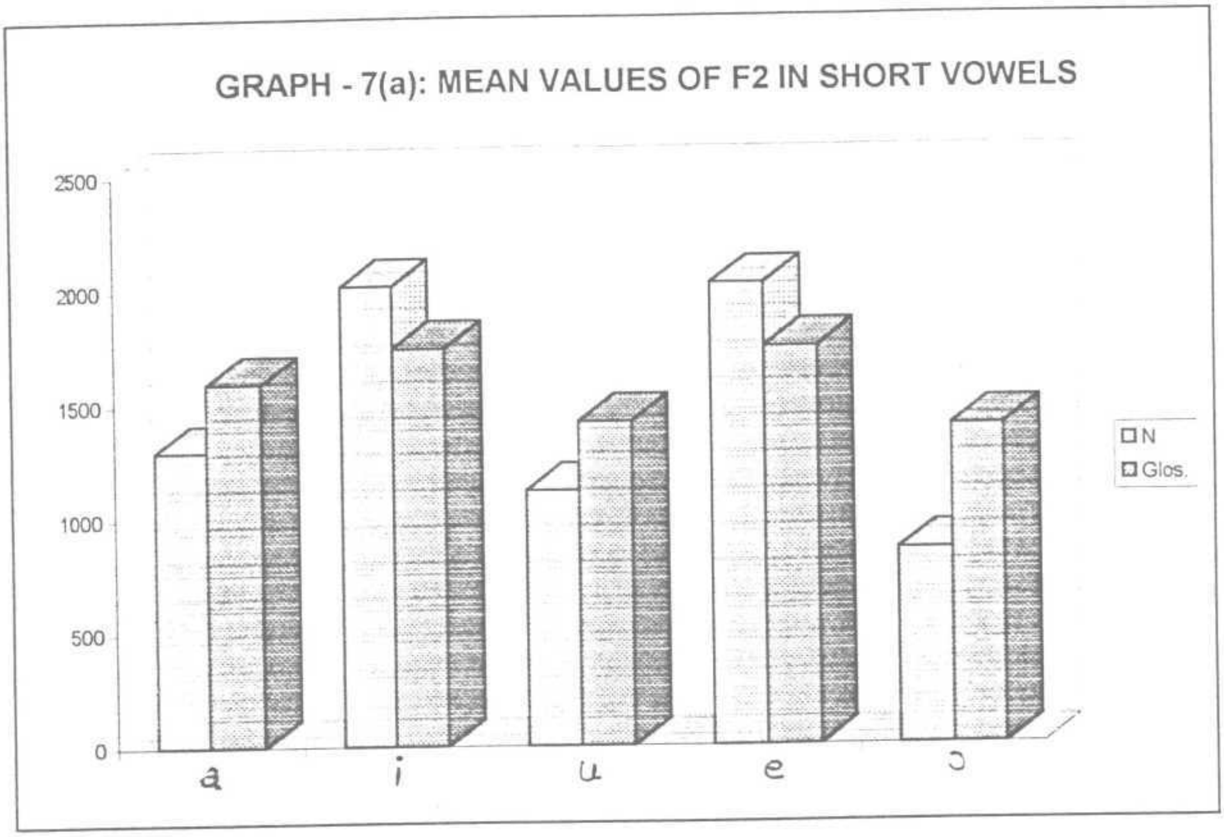
	NORMAL				GLOSSECTOMEE				Mean difference (N & Gloss)
V	N	MEAN	SD	RANGE	N	MEAN	SD	RANGE	
*a	5	1295.2	81.34	1207-1396 (189)	5	1593.2	259.56	1270-1929 (659)	- 298
*i	5	2016.8	104.94	1929-2180 (251)	5	1743.4	149.58	1615-1992 (377)	+ 273.4
*u	5	1119.4	579.38	768-2149 (1381)	5	1422.2	226.29	1051-1662 (611)	- 302.8
*e	5	2023	49.64	1960-2086 (126)	5	1742.2	126.54	1615-1929 (314)	+ 280.8
*°	5	856	183.36	705-1145 (440)	5	1397.2	256.13	956-1615 (659)	- 541.2

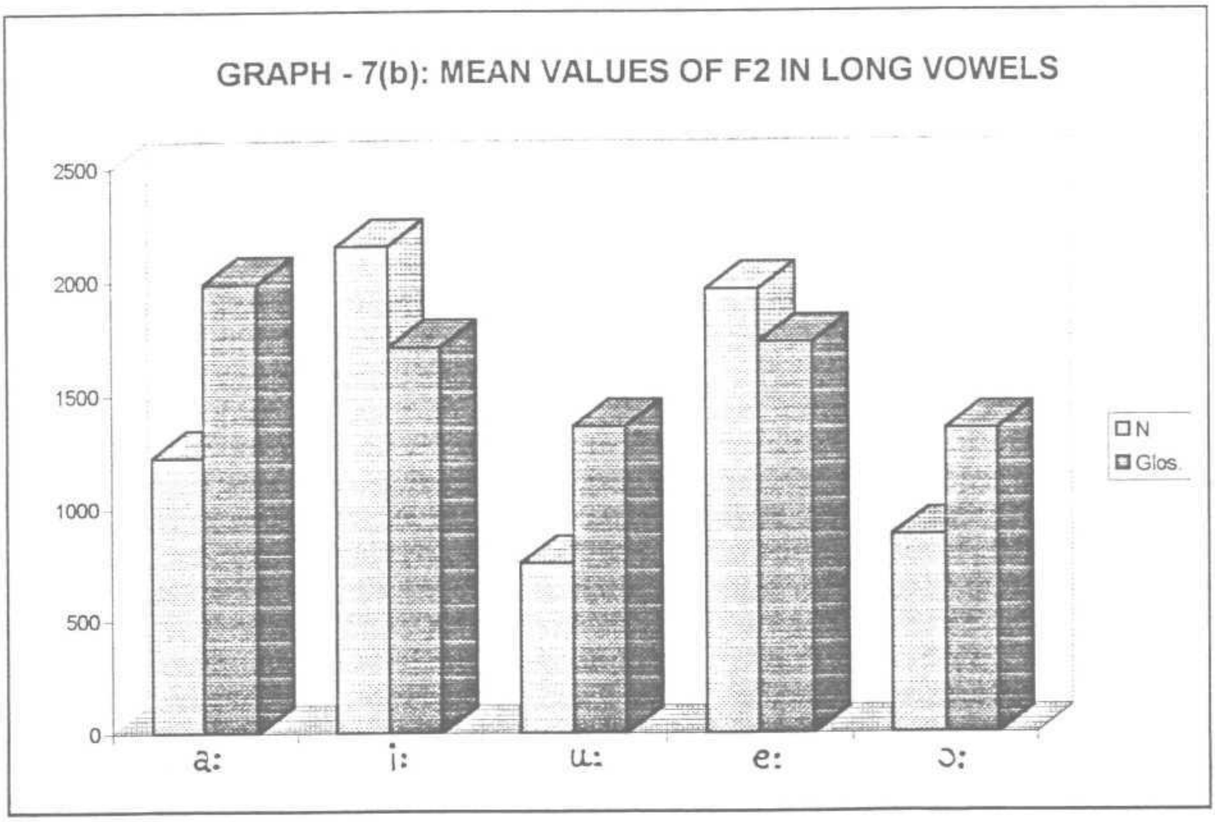
* *Significance difference between the means at 0.05 level.*

Table 10b: Mean, standard deviation (SD), range and mean difference values of F2 for long vowels in the speech of the normals and glossectmees.

	NORMAL				GLOSSECTOMEE				Mean difference (N & Gloss)
V	N	MEAN	SD	RANGE	N	MEAN	SD	RANGE	
*a:	5	1226.2	112.04	1082-1364 (282)	5	1990.4	492.24	1451-2651 (1200)	- 764.2
*i:	5	2154.8	111.76	2054-2305 (251)	5	1712.4	155.35	1560-1960 (400)	+ 442.4
*u:	5	757	148.16	666-1019 (353)	5	1361	254	1019-1654 (635)	- 604
*e:	5	1965.8	40.16	1898-1992 (94)	5	1733	124.95	1584-1866 (282)	+ 232.8
*O:	5	879.6	139.31	745-1082 (337)	5	1347	300.18	956-1741 (785)	- 467.4

* *Significance difference between the means at 0.05 level.*


GRAPH - 7(a): MEAN VALUES OF F2 IN SHORT VOWELS
2500
2000
1500
1000
500
0
a
i
u
e
ɔ
N
Glos.


GRAPH - 7(b): MEAN VALUES OF F2 IN LONG VOWELS
2500
2000
1500
1000
500
0
a:
i:
u:
e:
ɔ:
N
Glos.

The values of mean F2 of all long vowels produced by the glossectomy group were higher than that of the normal group except for vowel /i:/ and /e:/ which was lower by 442.4 Hz and 232.8 Hz respectively. The difference in mean F2 between the two groups for vowels /a:/, /i:/, /u:/, /e:/ and /o:/ were 764.2Hz, 442.4 Hz, 604 Hz, 232.8 Hz, and 467.4 Hz respectively.

Significant difference was found for all the long vowels.

The hypothesis stating that there is no significant difference between the means of F2 values of glossectomees and normals was rejected for all the long and short vowels.

(c) Third Fonnant Frequency:

Table lla and table l1b provide mean, standard deviation, and range of F3 for short and long vowels in the speech of the glossectomy and normal groups respectively. Graph 8a and graph 8b provide mean values of the same.

The glossectomy group had higher F3 than those of the normal group. The mean F3 values of all short vowels produced by the glossectomy group was found to be higher than that of normal group. The difference in mean F3 between the two groups for vowels /a/,/i/,/u/,/e/ and /O/ were 306.6 Hz, 76.4 Hz, 177.4 Hz, 178.8 Hz and 365 Hz respectively.

Table 11a: Mean, standard deviation (SD), range and mean difference values of F3 for short vowels in the speech of normals and glossectomees.

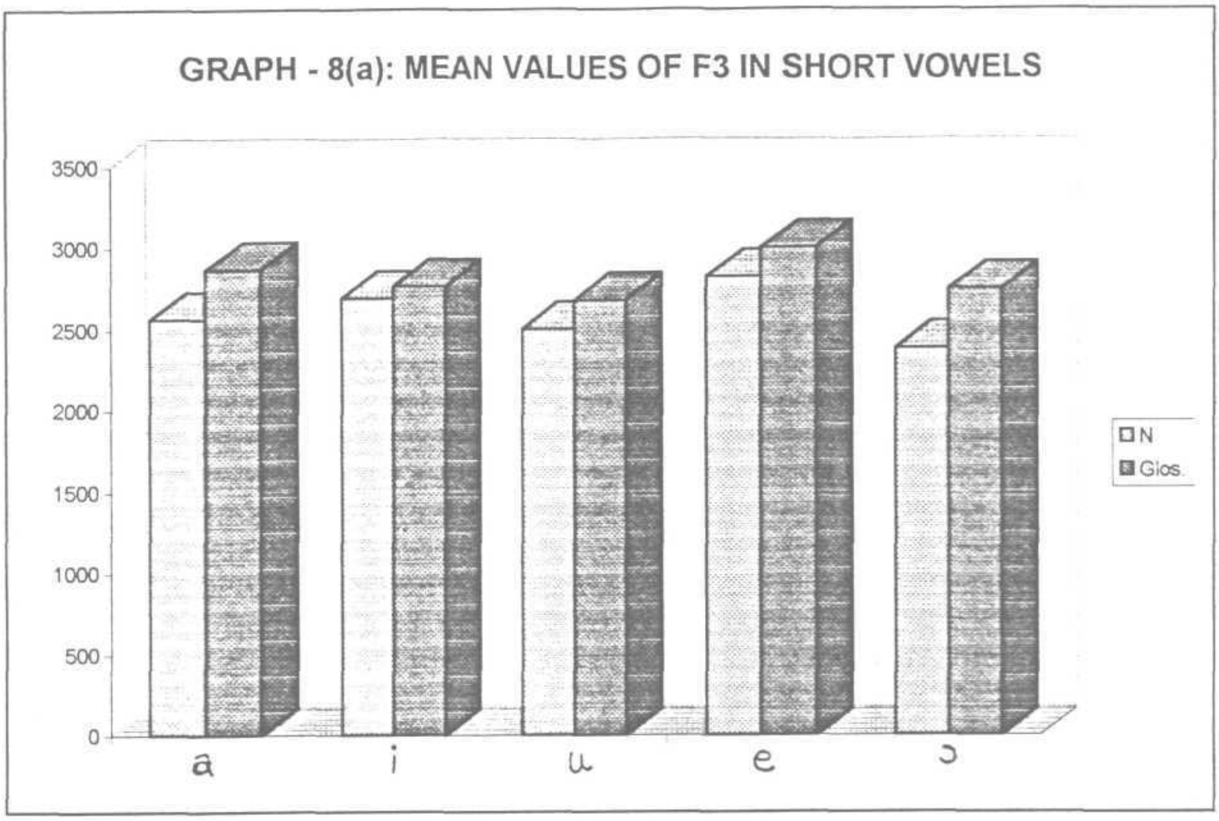
	NORMAL				GLOSSECTOMEE				Mean difference (N & Gloss)
V	N	MEAN	SD	RANGE	N	MEAN	SD	RANGE	
*a	5	2561.2	211.37	2337-2894 (557)	5	2867.8	371.92	2266-3192 (926)	- 306.6
*i	5	2688.2	60.28	2588-2745 (157)	5	2764.6	67.77	2690-2870 (180)	- 76.4
*u	5	2500	564.27	1992-3466 (1474)	5	2677.4	308.17	2149-2902 (753)	- 177.4
*e	5	2824.6	331.52	2556-3396 (840)	5	3003.4	226.4	2870-3403 (533)	- 178.8
*o	5	2381	81.04	2243-2447 (204)	5	2746	178.35	2611-2964 (353)	- 365

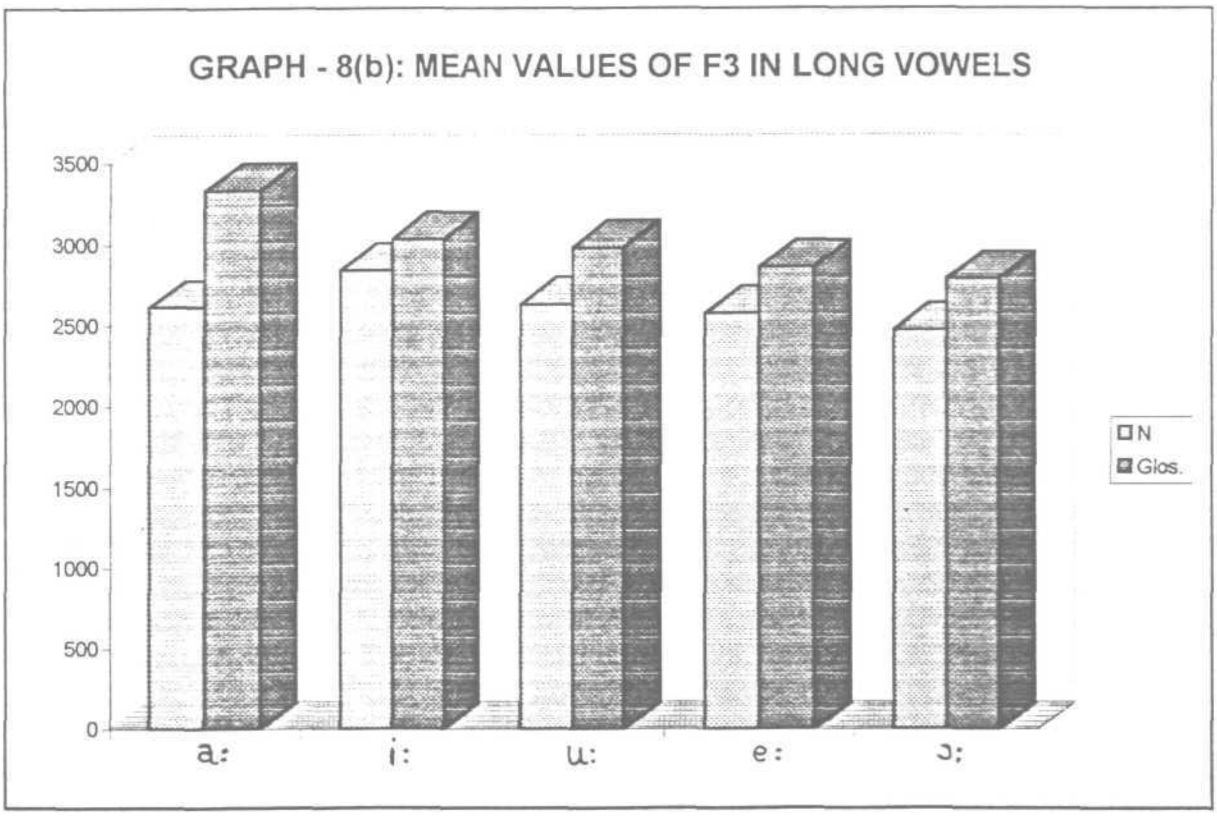
* *Significance difference between the means at 0.05 level.*

Table 11b: Mean, standard deviation (SD), range and mean difference values of F3 for long vowels in the speech of normals and glossectomees.

	NORMAL				GLOSSECTOMEE				Mean difference (N & Gloss)
V	N	MEAN	SD	RANGE	N	MEAN	SD	RANGE	
*a:	5	2613	135.68	2431-2776 (345)	5	3332.8	988.87	2360-4972 (2612)	- 719.8
*i:	5	2838.	161.52	2713-3121 (408)	5	3030.2	223.54	2839-3403 (564)	- 191.6
*u:	5	2627	336.4	2164-3027 (863)	5	2978.2	315.4	2713-3466 (753)	- 351.2
*e:	5	2571.4	135.54	2494-2807 (313)	5	2856.2	249.92	2494-3200 (706)	- 284.8
*o:	5	2467	279.52	2149-2909 (760)	5	2786.8	374.21	2517-3403 (886)	- 319.8

* *Significance difference between the means at 0.05 level.*


GRAPH - 8(a): MEAN VALUES OF F3 IN SHORT VOWELS
3500
3000
2500
2000
1500
1000
500
0
N
Glos.
a
i
u
e
ɔ


GRAPH - 8(b): MEAN VALUES OF F3 IN LONG VOWELS
3500
3000
2500
2000
1500
1000
500
0
N
Glos.
a:
i:
u:
e:
ɔ:

The mean F3 values of all long vowels produced by the glossectomy group was found to be higher than that of normal group. The difference in mean F3 between the normals and glossectomees for /a:/, /i:/, /u:/, /e:/ and /o:/ were 719.8 Hz , 191.6 Hz, 351.2 Hz, 284.8 Hz, 319.8 Hz respectively.

Significant difference was found for F3 between the normal and glossectomy group.

Hence, the hypothesis stating that there is no significant difference between the means of F3 values of normals and glossectomees was rejected.

7. Bandwidth:

Table 12a, table 12b and table 12c provides mean, standard deviation and range of Bl, B2 and B3 respectively for normals and glossectomees.

Graph 9a, graph 9b and graph 9c provide the mean values of the same.

The three bandwidths Bl, B2, and B3 were determined for all the vowels.

In general the bandwidth were higher for normals than the glossectomees.

Table 12a: Mean, standard deviation (SD), range and mean difference values of B1 for normals and glossectomees.

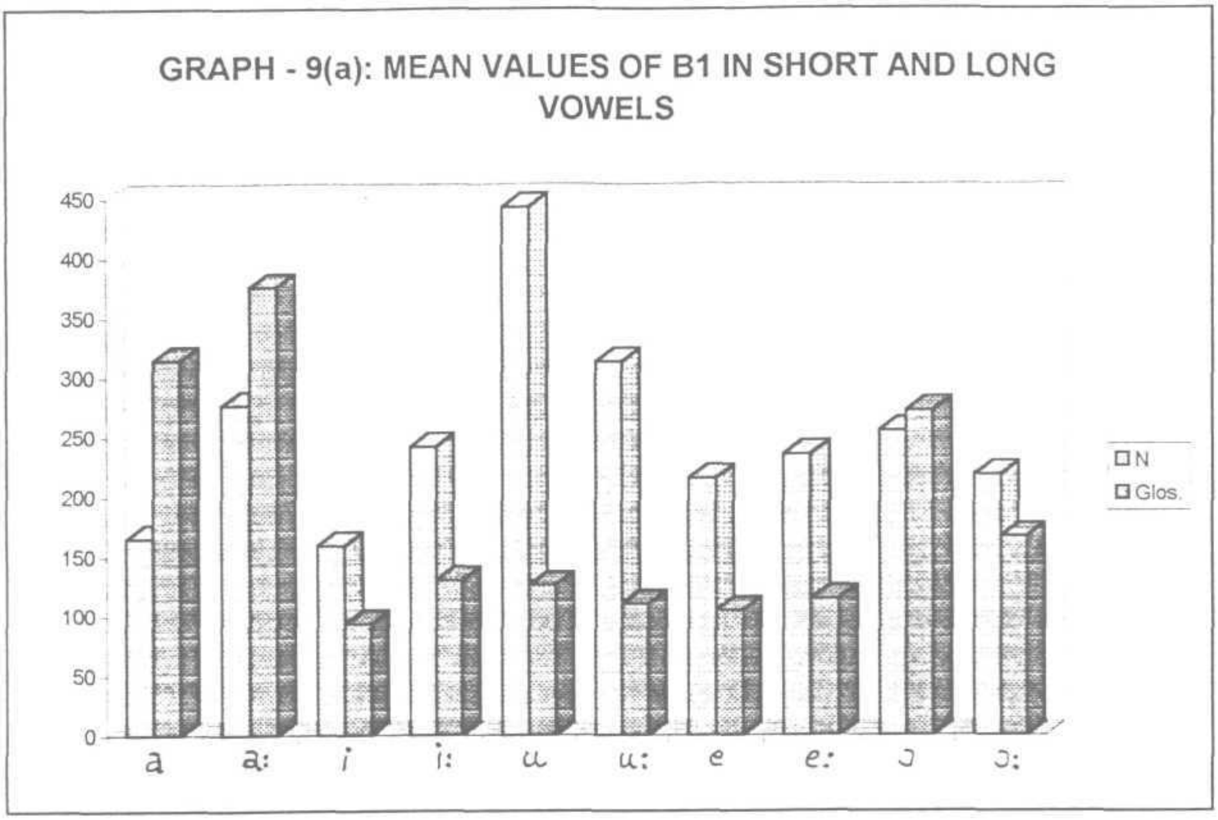
	NORMAL			GLOSSECTOMEE			Mean difference (N & Gloss)
V	MEAN	SO	RANGE	MEAN	SD	RANGE	
*a	165.4	61.8	102-238 (136)	314.4	44.1	259-370 (111)	- 149
a:	276.6	138.31	160-464 (304)	375.4	115.37	217-490 (273)	- 98.8
i	159.4	59.96	105-243 (138)	93	59.06	58-196 (138)	+ 66.4
i:	241.6	193.67	94-568 (474)	129.80	110.13	51-322 (271)	+ 111.8
*u:	442.4	238.63	168-704 (536)	125.80	55.83	67-209 (158)	+ 316.6
u:	312.6	245.52	128-744 (616)	110	33.41	66-153 (87)	+ 202.6
e	215.4	174.22	71-512 (441)	104.2	37.35	57-153 (96)	+ 111.2
e:	235.2	139.9	96-411 (315)	114.2	23.03	80-143 (63)	+ 121
o	255.2	56.30	173-329 (156)	271.8	149.46	105-402 (297)	- 16.6
o:	218	105.72	104-371 (267)	166	48.28	129-250 (121)	+ 52

* *Significance difference between the means at 0.05 level.*

Table 12b: Mean, standard deviation (SD), range and mean difference values of B2 for normals and glossectomees.

	NORMAL			GLOSSECTOMEE			Mean difference (N & Gloss)
V	MEAN	SD	RANGE	MEAN	SD	RANGE	
a	322.6	101.6	203-431 (228)	393.6	115.02	232-494 (262)	- 71
*a:	342.4	131.96	216-504 (288)	195.2	71.88	98-299 (201)	+ 147.2
i	390	200.19	246-742 (496)	220.2	121.11	105-397 (292)	+ 169.8
i:	312.8	220.64	146-684 (538)	239	135.94	130-474 (344)	+ 73.8
*u	693.6	104.65	534-785 (251)	283	163.63	116-499 (383)	+ 410.6
*u:	536.2	207.2	361-882 (521)	259	98.34	155-394 (239)	+ 277.2
e	325.6	153.47	227-597 (370)	**193**	79.64	105-288 (183)	+ 132.6
e:	431.6	219.71	268-807 (539)	236.8	97.74	97-324 (227)	+ 194.8
*o	519.80	181.84	352-815 (463)	322.6	94.97	247-485 (238)	+ 197.2
o:	450.6	259.34	229-848 (619)	396.2	102.61	311-566 (255)	+ 54.4

* *Significance difference between the means at 0.05 level.*


GRAPH - 9(a): MEAN VALUES OF B1 IN SHORT AND LONG VOWELS
450
400
350
300
250
200
150
100
50
0
a
a:
i
i:
u
u:
e
e:
ɔ
ɔ:
N
Glos.

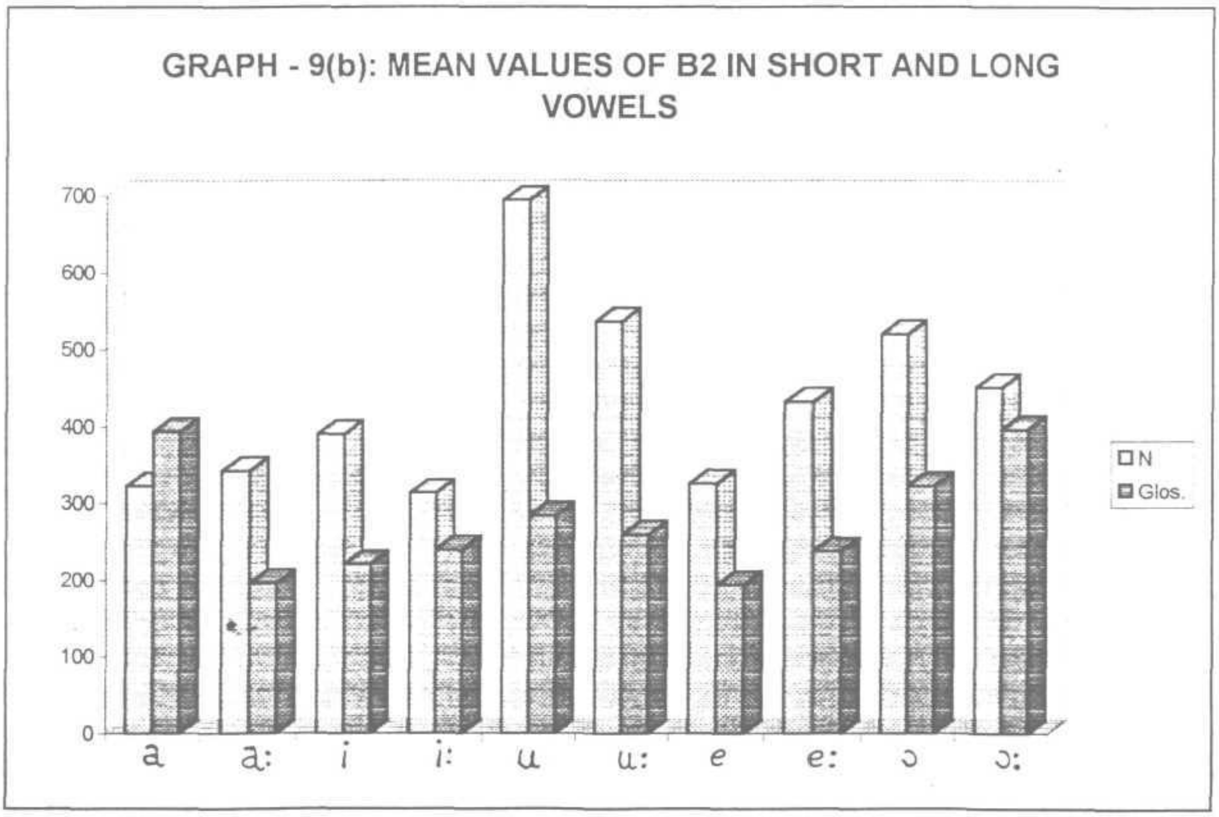
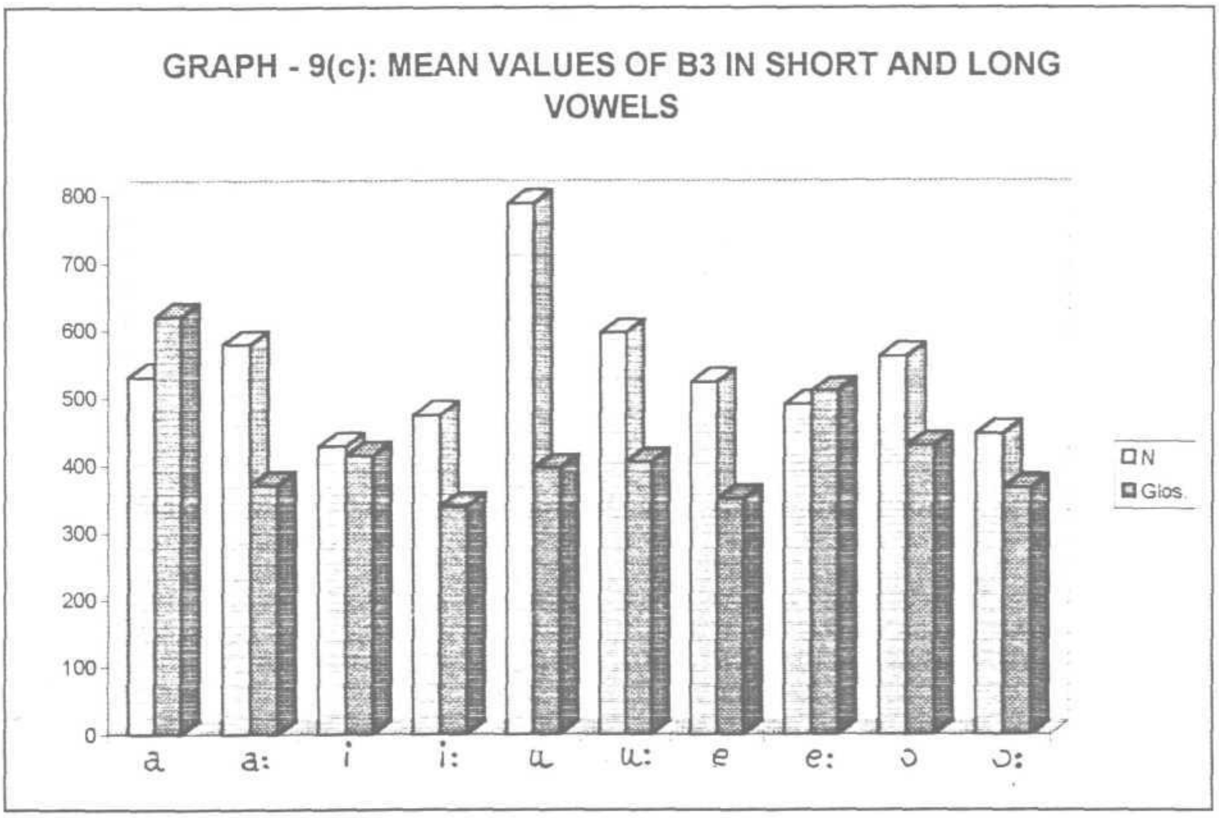

GRAPH - 9(b): MEAN VALUES OF B2 IN SHORT AND LONG VOWELS
700
600
500
400
300
200
100
0
a
a:
i
i:
u
u:
e
e:
ɔ
ɔ:
N
Glos.

Table 12c: Mean, standard deviation (SD), range and mean difference values of B^3 for normals and glossectomees.

	NORMAL			GLOSSECTOMEE			Mean difference (N & Gloss)
V	MEAN	SD	RANGE	MEAN	SD	RANGE	
a	531	137.32	380-678 (298)	620.8	211.83	412-853 (441)	- 89.8
a:	579	199.19	358-868 (510)	370.4	134.7	182-531 (349)	+ 208.6
i	428.2	231.09	132-781 (649)	414	129.61	230-566 (336)	+ 14.2
i:	474.8	247.38	215-862 (647)	339.2	107.05	212-463 (251)	+ 135.6
*u	787.2	212.03	495-999 (504)	395.6	158.64	226-628 (402)	+ 391.6
*u:	596.2	121.67	446-738 (292)	404.6	145.84	254-591 (337)	+ 191.6
e	523.2	207.27	334-749 (415)	350.2	117.14	240-550 (310)	+ 173
e:	490.2	163.76	273-701 (428)	510.2	221.92	342-875 (533)	- 20
0	561.2	182.77	329-787 (458)	429.2	268.67	116-668 (552)	+ 132
o:	447	148.02	317-676 (359)	366.4	179.79	96-516 (420)	+ 80.6

* *Significance difference between the means at 0.05 level.*


GRAPH - 9(c): MEAN VALUES OF B3 IN SHORT AND LONG VOWELS
800
700
600
500
400
300
200
100
0
a
a:
i
i:
u
u:
e
e:
ɔ
ɔ:
N
Glos.

B1 for normals were higher than the glossectomees except for vowels /a/, /a:/ and /o/.

Significant difference were found for vowels /a/ and /u/.

B2 was also found to be higher in normals than glossectomees except for /a/. Significant difference was found for vowels /a:/, /u/,/u:/ and /o/.

B3 was found to be higher in normals when compared to glossectomees except for /a/ and /e/. Significant difference was found for vowels /u/ and /u:/.

Thus it can be noted that Bl, B2 and B3 for the vowel /a/, Bl and B2 for /a:/ and */O/* and B2 and B3 for /u/ and /u:/ is higher in glossectomees than normals.

B3 for /a:/ and /o/, Bl for /u/ and /u:/, and B1,B2, B3 for /i/, /i:/,/e/,/e:/ and /o:/ was higher in normals than glossectomees.

On group statistics it was found that there was no significant difference for Bl between normals and glossectomees.

However, significant difference was found for B2 and B3 between the two groups. The hypothesis stating that there is no significant difference in the means of Bl, B2 and B3 between the two groups is rejected for B2 and B3 and accepted for Bl.

8. Total Word duration:

Table 13 provide mean, standard deviation and range of word duration for normal and glossectomees.

Graph 10 provide the mean values of the same.

The mean word duration produced by the glossectomees were found to be higher than that of normals.

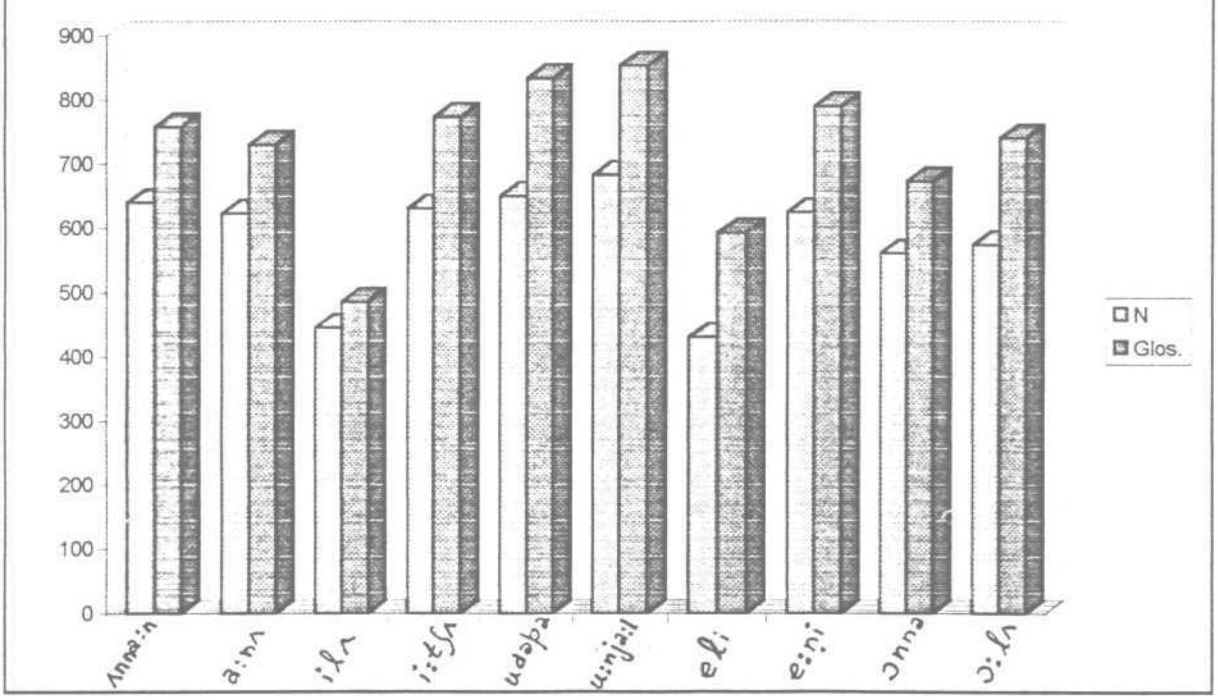
The mean word duration produced by the normals had longest duration of 682.40 msec for /u:nja:l/ followed by words /udspa/, /Annarn/, /i:tp\/, /e:ni/, /a:n//, /^:1A/, /onna/ / H A / and /eli/ with word durations of 649.4 msec, 639.80 msec, 629.8 msec, 623.8 msec, 622.4 msec, 573 msec, 559.80 msec, 444.6 msec and 429.6 msec respectively. Where as glossectomees had the word duration in the order of /urnjal/, /udopa/, /e:ni/, */i:tj*\/, Annarn/, /O:1A/, /a:nA/, */jnna/* /eli/ and / H A / with word durations of 852.40 msec, 832.4 msec, 788.4 msec, 772.4 msec, 757.4 msec, 740 msec, 729.8 msec, 672.40 msec, 592.4 msec and 484.8 msec respectively.

Table 13: Mean, Standard deviation (SD), range and mean difference values of word duration in normals and glossectomees.

	NORMAL			GLOSSECTOMEE			Mean difference (N & Gloss)
Words	MEAN	SD	RANGE	MEAN	SD	RANGE	
Ann3:n	639.8	77.85	512-712 (200)	757.4	177.09	525-950 (425)	- 117.6
a:nA	622.4	131.8	400-750 (350)	729.8	116.37	612-875 (263)	- 107.4
ilA	444.6	156.04	262-687 (425)	484.8	89.97	362-600 (238)	- 40.2
i:tf$_A$	629.80	117.39	425-725 (300)	772.4	164.41	550-975 (425)	- 142.6
udapj	649.6	75.04	537-712 (175)	832.40	176.45	537-950 (413)	- 182.8
*u:nj <a:l	682.40	97.65	537-800 (263)	852.40	118.65	725-975 (250)	- 170
*eli	429.6	72.62	337-537 (200)	592.4	123.59	375-675 (300)	- 162.8
e:ni	623.S	133.39	400-725 (325)	788.4	154.69	575-980 (405)	- 164.6
onn3	559.80	107.21	375-637 (262)	672.40	162.96	450-812 (362)	112.6
O:1A	573	137.91	400-750 (350)	740	143.17	550-875 (325)	- 167

* *Significance difference between the means at 0.05 level.*

GRAPH - 10: MEAN VALUES OF TOTAL WORD DURATION



In both the groups the word /u:nja:l/ had the longest duration.

The mean difference between normals and glossectomees for the words /Anna:n/, /a:nA/, / H A / , */iit.J\/,* /udspa/, /u:nja:l/, /eli/, /e:ni/, /0nn3/ and /O:1A/ were 117.6 msec, 107.4 msec, 40.2 msec, 142.6 msec, 182.8 msec, 170 msec, 162.8 msec, 164.6 msec, 112.6 msec, & 167 msec respectively.

The mean word duration produced by the glossectomy group were found to be higher than that of the normal group by 40.2 - 182.8 msec.

Significant difference between the normal and glossectomy groups was found for words /u:nja:l/ and /eli/. No significant difference was found for the other words between the two groups.

Thus, the hypothesis stating that there is significant difference between the mean word duration of the normals and the glossectomees was rejected for words /u:nja:l/ and /eli/ and accepted for the other words.

9. INTELLIGIBILITY

Table 14 and graph 11 provide the mean intelligibility scores (percentage) computed from the scores of five judges for the normal and glossectomy groups.

The speech of normal group was more intelligible than the glossectomee speech. Inspection of the range indicated that there were speakers in glossectomy group who had achieved 91% intelligibility. The mean intelligibility scores of the glossectomy group was 61.72% and that for the normal group was 99.54%. The scores ranged from 40-91% and 98-100% in glossectomee's and normals respectively.

Table 14: Mean and Range of intelligibility scores (percentage).

	MEAN	RANGE
Glossectomee	61.72%	40-91%
Normals	99.54%	98-100%
Gloss + Normals	80.63%	40-100%

10. ACCEPTABILITY:

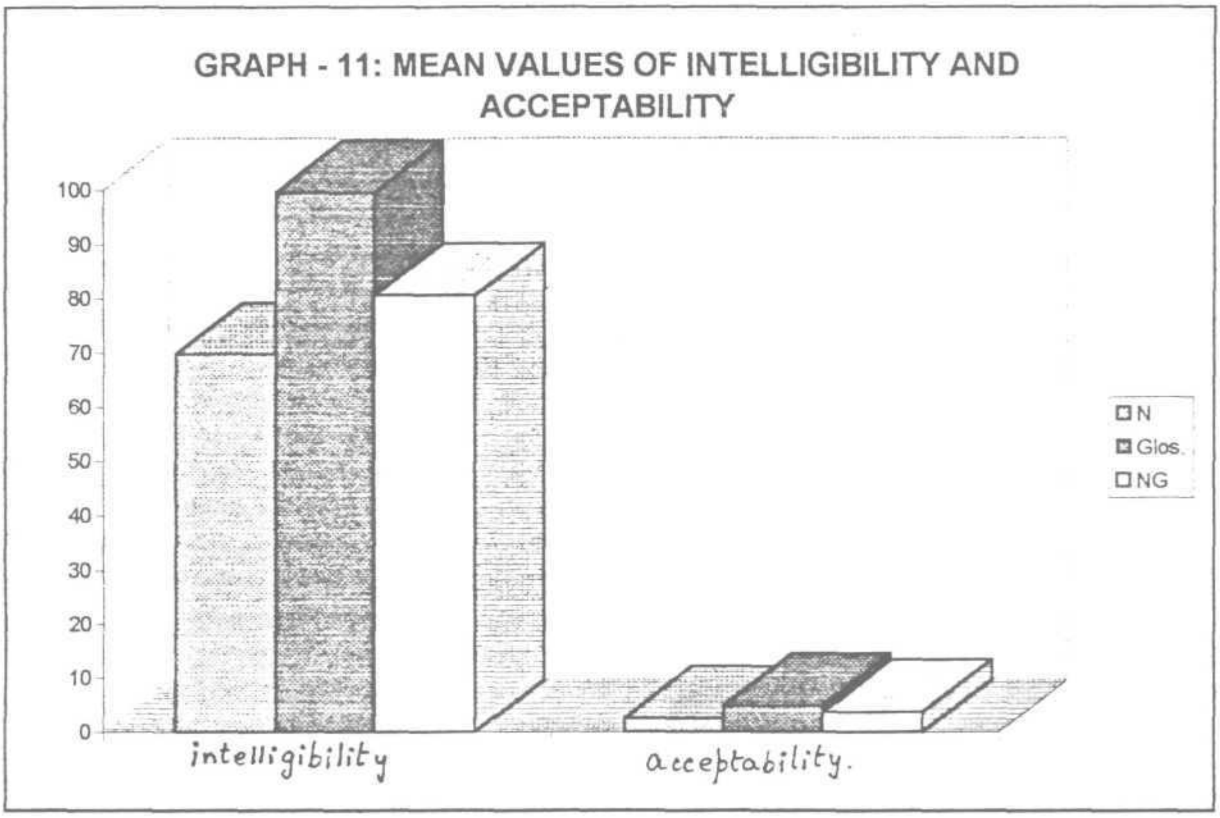
A five point scale with one being the "least acceptable" and five being the "most acceptable" was used to rate the acceptability of speech of subjects of normals and glossectomee's. Five judges rated the acceptability of the speakers individually.

Table 15 and graph 11 depict the judgements on the acceptability ratings for both the groups. The glossectomy group showed lower acceptability ratings as compared to normals.

The glossectomee speakers had a mean rating of 2.5 and normals had a mean rating of 4.88. The higher limit of the range in the glossectomy group (1-3.5) did not fall in the range of the normal group (4.5-5).

Table 15: Mean and Range of acceptability rating for normals and glossectomee's.

	MEAN	RANGE
Glossectomee	2.5	1-3.5
Normal	4.88	4.5-5



GRAPH - 11: MEAN VALUES OF INTELLIGIBILITY AND ACCEPTABILITY

DISCUSSION

Antoni (1984) reported that rapidity of the utterance of the isolated syllables and rate of articulation of the speech sounds in spontaneous speech and reading is slower in patients after tongue resection. Kent and Read (1995) reports, speaking rate influences the vowel duration, i.e., slower speaking rate increases the vowel duration.

In the present study it was found that glossectomee's had a longer vowel duration than normals. The longer vowel duration in glossectomee's could be attributed to decreased speech rate due to restricted movement of the subcutaneous flap which replaces the tongue.

Glossectomee's had longer closure duration than normals. Increased closure duration can be attributed to incomplete closure because of which it takes longer time to build the intra oral pressure required for the production of consonants. The vowel portion and the closure could not be separated for the consonants /p/, /b/, /d/, /g/, /t/, and /d/ . Therefore, closure duration could not be measured for majority of the glossectomy subjects.

Voice onset time (VOT) varies inversely with the rate at which oral release gesture is made (Summerfield and Haggard, 1977). In the present study it was found that glossectomy subjects had shorter VOT when compared to normals. Inadequate articulatory constriction, reduced intra oral pressure, and longer time taken to make an oral release gesture due to lack of mobility of flap could have contributed to lowered VOT in glossectomy subjects.

Kent and Read (1995) reported that all stop consonant require an articulatory blockage of 50-100 msec and is subsequently released with a burst of air as the air pressure impounded behind the obstruction escapes. In this study, burst was not observed in glossectomy subjects for /t/, /d/, /k/, /g/, /t/ and /d/. Burst was seen for /p/ and /b/.

However the energy concentration was reduced when compared to normals. This could be due to reduced intra oral pressure in glossectomy speakers.

Absence of burst in glossectomy subjects can be attributed to the lack of articulatory contact of the flap with the velum, palate and alveolus which leads to reduced pressure behind the obstruction and air escape through the incomplete constriction. Due to this lack of articulatory contact and absence of burst, the stop consonants were perceived to be distorted. Deborah (1982) also reported that stop burst was not present in the spectrograms of the prevocalic stop consonants /p,b,t,d/. Due to the absence of burst in glossectomee speakers, burst frequency could not be measured in this group for /t/, /d/, /k/, /g/, /t/ and /d/. Burst frequency measured for /p/ and /b/ revealed higher burst frequency in glossectomy group when compared to normals. Absence of burst can be attributed to reduced pressure due to inadequate contact of the flap with the alveolus, palate and velum.

Venkatesh (1995) has stated that F_1 increased as the point of constriction moved from front to back position of the oral cavity and F_1 decreased as the height of the tongue increased. In the present study it was found that glossectomy subjects had higher F_1 when compared to normals. These findings are in contrast to the findings of Morrish (1984), where two highly intelligible total glossectomees had F_1 corresponding to that of normal speakers for the vowels /i,e,a,o,u/.

Higher F_1 in glossectomees could be due to,

- Lack of elevation of the flap, and
- Restricted movement of the flap towards the front of the oral cavity.

The frequency of F_2 tends to be lowered by a back tongue constriction and raised by a front tongue constriction (Picket, 1980). Venkatesh (1995) has reported that F_2 decreased as the point of constriction moved from front to back position of the oral cavity. The results of the present study reveals that F_2 was raised in glossectomy speakers when compared to normals except for vowels /i/, /i:/, /e/ and /e:/. In contrary to these findings, Morrish (1984) found reduced F_2 in two highly intelligible total glossectomee's for vowels /i,e,a,o,u/.

Raised F_2 in glossectomee's for vowels /a/, /a:/, /u/, /u:/, / o / and /o/ and lowered F_2 for vowels /i/, /i:/, /e/ and /e:/ can be explained as,

the flap was not back enough in the oral cavity for the production of /a/, /a:/, /u/, /u:/, (o) and (o:), hence raised F_2.

the flap was not front enough in the oral cavity for the production of /i/, /i:/, /e/ and /e:/, hence lowered F_2.

Deborah (1982) reported that F_1 and F_2 could not be clearly separated from one another. Kent and Read (1995) reported that constriction at the labial, pharyngeal, and palatal level lowered the frequency of F_3 and constriction near the larynx raised the frequency of F_3. Picket (1980) reported of lowered frequencies of F_1, F_2 and F_3 by lip rounding. More the rounding, the more the constriction and the more the formant frequencies are lowered. F_3, in the present study was higher in glossectomees than normals. The energy of F_3 was also low for all the vowels. However, the F_3 was measured by increasing the gain. Deborah (1982) in his study found that glossectomees had low energy at F_3 and that it was not recorded. Inadequate constriction at the labial and palatal level could have contributed to raised frequency of F_3 in glossectomees. Poor lip sounding due to hemimandibulectomy could also have contributed to raised frequency of F_3 in glossectomees.

The formant bandwidth increased as the formants increased in normals and glossectomees. This result is in support with the results of study by Venkatesh (1995). He found that formant bandwidths increased as the formants increased. This was also supported by Kent and Read (1995).

It was also found that the formant frequencies were inversely proportional to formant bandwidth in normals and in glossectomees. The formant frequencies (F_1, F_2, F_3) was higher in glossectomees than normals, and the bandwidth was lower in glossectomees than normals.

Word duration increases for long vowels than for short vowels by 100 msec (Venkatesh, 1995). This supports the findings of the present study, where, it was found that words with long vowels had longer duration when compared to words with short vowels except for /A nna:n/ and /a:nA/ in both the groups of subjects. /a:nA/ had shorter duration than £ /nna:n/. This could be due to more number of consonants in / Annarn/ than /a:n-\/.

It was also found that glossectomees had longer word duration than normals. Restricted movements and reduced mobility of the subcutaneous flap, reduces the rate of speech and hence the vowel duration is increased. This increase in vowel duration will in turn increase the word duration in glossectomees.

In contrary to the results of Conrad La Riviere (1974), where the control subjects were significantly more intelligible than the glossectomees for all materials except the sentences, in the present study it was found that the glossectomee subjects were highly unintelligible than normals for the sentence material. On a 5-point acceptability rating scale, the glossectomee speakers were rated to be between 1-3.5 and normals were rated to be between 4.5-5.

The intelligibility scores ranged from 40-91% in glossectomee's and 98-100% in normals. Though varying in methodology, Skelly (1971) found a 0-8% intelligibility in total glossectomee's and 6-24% intelligibility in partial glossectomee's, which was much lower than the findings of the present study. Conrad La Riviere (1974) also found that the control subjects were significantly more intelligible than the glossectomee's for all materials except the sentences.

Compensatory articulatory postures acquired by the glossectomee speakers in the span of one year post surgery could have led to a high intelligibility scores in glossectomee speakers.

Therefore, the findings of the present study were as follows:

1. Glossectomy speakers had much longer vowel duration than normals.
2. Closure duration was slightly longer in glossectomees when compared to normals.
3. Shorter VOT in glossectomees than normals.
4. Absence of burst for /t/, /d/, /k/, /g/, /t/, and /d/.
5. Slightly longer burst duration and higher burst frequency for /p/ and /b/ in glossectomees than normals.

6. Glossectomees had higher formant frequencies (F_1, F_2, F_3) when compared to normals.
7. Large bandwidth in glossectomy speakers.
8. Longer word duration in glossectomee's.
9. Lower intelligibility scores in glossectomee's than normals.
10. Normal speaker's were rated to be highly acceptable than glossectomee speakers.

Thus, it can be concluded that intelligibility for single words was higher than for sentences in glossectomee's. This shows the lack of coarticulation due to restricted movement of the flap in continuous speech. To achieve correct articulation, an adequate constriction, an adequate pressure build up behind the constriction and an adequate rate of oral release gesture is required which lacks in glossectomee speakers.

SUMMARY AND CONCLUSION:

Speech, like all other modes of communication, is essentially a social activity. It has enabled individuals to adjust themselves to their surroundings and to learn to customs, the background, of the groups into which they have come; it has made it possible for groups themselves to unite into socially organic units and to carry on their normal activities with a minimum of friction and a maximum of effectiveness; and finally it has provided a means by which one individual may exercise a measure of control over the behaviour of those about him. (Gray and wise, 1959).

Speech, to be most effective, should have agreeable voice quality and the voice must be distinctly articulated. To reach our social objectives in speech, our words must be understood and easily understood. Every sound in a spoken word must be given its proper value; the vowels must be clearly enunciated, the consonants sharply articulated. (Gray and Wise, 1959).

The entire vocal tract contributes in the production of speech. Within the oral cavity, among the various articulators, the tongue plays an important role in articulation, control of secretions, formation of a bolus, propulsion of bolus toward the pharynx, cleaning the palate and initiation of swallow reflex (Godoy 1991).

Travis (1988) reports that the tongue is crucial to speech production because it is the prime determinant of vocal tract shape. However Froeschels (1933), Green (1937) stated that the tongue is not essential for speech, and that congenital absence or adventitious loss of the tongue need not prevent a victim of such loss from learning to talk. Despite this claim, the tongue is extremely important, it is due to the adept action of the tongue that most of the compensatory movements of speech are achieved by those patients whose oral deformities preclude the development of normal articulatory movements.

Glossectomy prevents normal articulation of the speech sounds. Vowels, semivowels and lingual consonants are the speech segments most seriously affected by a glossectomy procedure, though acoustic characteristics of all speech sounds may be influenced by the altered vocal tract.

The present study aimed at comparing the glossectomee speech and normal speech at word level to determine the similarities and differences between the two. The parameters studied were,

- Formant frequencies (Fl, F2, F3)
- Bandwidth (Bl, B2, B3)
- Burst frequency
- Vowel duration
- Closure duration
- voice onset time
- Burst duration
- Total word duration
- Acceptability and intelligibility

Ten Malayalam (Five normals and Five glossectomee) speakers participated in the study. The subjects were instructed to produce twenty six words followed by a carrier phrase. They were also instructed to read a standard Malayalam passage.

The speech samples were recorded in a sound treated room. Recordings were made on hi-bias metal cassettes, using a professional stereo cassette deck (Ahuja) and a AKG - D 222 dynamic cardioid microphone with a flat frequency response from 50-15,000 Hz. The microphone to mouth distance was approximately 10 cm for all the subjects.

For analysing the data, tape deck, antialiasing filter, A-D/D-A converter, PC, amplifier, speaker and a software developed by voice speech system, Bangalore was used.

The findings of the analysis were as follows:

1. The vowel duration was much longer in glossectomy speakers than the normal speakers. Significant difference was found between the two groups.
2. The closure duration in glossectomees was slightly longer than the normals. No significant difference was found.
3. Voice onset time was shorter in glossectomees when compared to the normals. Significant difference was found between normals and glossectomees.
4. Burst duration was slightly longer in normals when compared to glossectomees. However, majority of the glossectomy subjects did not show a burst for the bilabials alveolars, velars, dentals.
5. Burst frequency was higher in glossectomees than in normals. However, burst was not observed in majority of the glossectory subjects.
6. Formant frequencies (Fl, F2, F3) was higher in glossectomy speakers than normals. Significant difference was found for F2 and F3 between normals and glossectomees and no significant difference was found for Fl.
7. Bandwidth was more in normals than in glossectomees. Significant difference was found for B2 and B3. No significant difference was found for Bl.

8. Word duration was longer in glossectomees than in normals for all the ten words.
9. Intelligibility scores were much lower in glossectomees than normals.

RECOMMENDATIONS FOR FURTHER STUDY:

1. A similar study can be carried out on a larger group.
2. A similar study can be conducted using subjects with different types of glossectomes.
3. Studies of similar kind can be done in other languages.
4. A comparative study using subjects with and without palatal prosthesis can be carried out.

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APPENDIX - I

PATIENT DETAILS

	AGE/SEX	SURGERY DONE	DATE OF SURGERY	DATE OF RECORDING
CASE 1	56yrs/M	Complete resection, facial neck dissection, PMMC flap, medial petrygoidectomy	1.5.97	30.7.98
CASE 2	44yrs/M	Subtotal glossectomy, right facial neck dissection, PMMC flap, hemimandibulectomy	17.1.97	30.7.98
CASE 3	63yrs/M	Total glossectomy, partial neck dissection	2.11.98	16.11.98
CASE 4	56yrs/F	Wide total excision, neck dissection, PMMC flap.	21.1.97	30.12.98
CASE 5	48yrs/M	Total glossectomy, hemimandibulectomy	22.5.97	30.12.98

APPENDIX - II

WORD LIST

1. /Kʌttil/
2. /Kitti/
3. /Kudʌ/
4. /t̪ettə/
5. /Kodt̪u/
6. /d̪i:pʌm/
7. /ribʌn/
8. /pa:tə/
9. /t̪a:Kɔl/
10. /Khʌgʌm/
11. /Kʌthʌkʌli/
12. /gʌd̪a:/
13. /bʌs/
14. /tap/
15. /dʌbbi/
16. /d̪ʌja:/
17. /ʌnna:n/
18. /a:nʌ/
19. /ilʌ/
20. /i:tʃʌ/
21. /udəpə/
22. /u:nja:l/
23. /eli/
24. /e:ṇi/
25. /onnə/
26. /o:lʌ/

APPENDIX : III

MALAYALAM PASSAGE

t̪eŋga:

mʌnuʃʌrkə sʌha:jʌm tʃejunnə mʌrʌŋgʌɭil ɔnna:ṇ t̪eŋgə. pʌlʌt̪ʌrʌm t̪eŋginkaigʌɭ undə. ivʌjil tʃilʌd̪ə urud̪ʌd̪um mʌṭə tʃilʌd̪ ni:ndʌd̪um a:ṇə. t̪eŋgʌ iɭʌpʌm airikumbɔɭ pʌtʃʌnʌrʌt̪ilum mu:kumbɔɭ iɭʌm mʌnjʌnʌrʌt̪ilum ma:rum. tʃilʌ kaigʌɭ mu:t̪a:ɭum pʌtʃʌnʌrʌt̪il t̪ʌnne irikjum. i: ka:jude purʌm kʌṭṭijuɭʌ t̪ɔdugɔndə mu:di irikjum. id̪inde uɭɭil tʃʌgʌrijim ʌd̪inde ʌgʌt̪ə ka:ṇunnə tʃirətejude uɭɭil t̪eŋgejem iɭʌnirum ka:ṇʌpʌdum. iɭənir kudikjuva:n vʌler rutʃiuɭɭʌd̪a:ṇə. id̪ə nʌllʌ auʃʌd̪əguṇʌm uɭɭʌdum a:ṇə. t̪eŋgejude tʃʌgəri kəjerunda:kuva:nʌm mud̪ʌvʌje tʃigeri met̪ejude ʌgʌt̪ə nʌrekjuva:nʌm upʌjogikjunnu.

APPENDIX - IV

DEFINITION

a) BURST DURATION (BD):

The production of a stop consonant involves the complete closure of the vocal tract during which air pressure is built up in the mouth. On the release of the constriction, the air pressure is abruptly released. The acoustic evidence of this release is a burst or transient and the burst duration is no longer than 5-40 msec. It is one of the shortest acoustic events that is commonly analyzed in speech.

b) VOWEL DURATION:

The vowel duration was considered to extend from the end of one periodic portion to the begining of the next a periodic portion.

C) CLOSURE DURATION:

Closure duration was the duration between the offset of resonance for the preceding vowel and the onset of burst for the stop consonant in intervocalic condition.

d) VOICE ONSET TIME (VOT):

VOT was defined as the time equivalent space from the onset of the stop release burst to the first vertical stiriation representing glottal pulsing

e) FORMANT FREQUENCIES F1,F2,F3:

The cursor was placed in the middle of the vowel portion and the formant frequencies were determined by using the sectioning method through the use of linear predictive coding (LPC) . This was done with 18 LPC coefficients. The frequencies at the peaks representing the formants were noted using the cursor.

f) BANDWIDTH:

The cursor was placed in the middle of the target vowel portion so as to avoid the formant transitions. The bandwidths were obtained by using the "PAT PLAY" of the software SSL.

g) BURST FREQUENCY:

To extract the burst frequency, the horizontal cursor was placed at the point of second formant, and thus the burst frequency was obtained.

h) TOTAL WORD DURATION (TWD):

Word duration is the time taken between initiation and termination of a word. The words were identified based upon the continuity of the waveform. The word duration was considered to extend from the beginning of the periodic signal to the end of the periodic signals.