Verification of the usefulness of Short Increment Sensitivity Index (SISI) test in determining Bone Conduction Thresholds

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A Dissertation Submitted in Part Fulfillment for the Degree of

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DEDICATED

TO MY PARENTS, SISTERS and TEACHERS

To Whom I Owe My Education

and Life.

CERTIFICATE

This is to certify that the Dissertation entitled "VERIFICATION OF THE USEFULNESS OF SHORT INCREMENT SENSITIVITY INDEX (SISI) TEST IN DETERMINING BONE CONDUCTION THRESHOLDS" is the bonafide work in part fulfillment for the degree of M.Sc. (Speech and Hearing), carrying 100 marks, of the student with Register No. 24.

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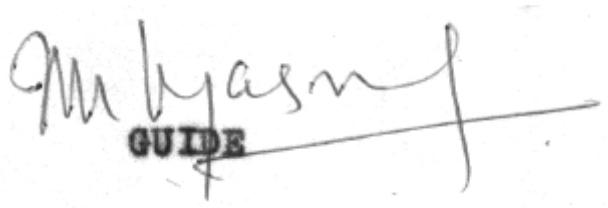
CERTIFICATE

This is to certify that this Dissertation has been prepared under my Supervision and Guidance.



DECLARATION

This Dissertation is the result of my own study undertaken under the guidance of Mr. M.N. Vyasamurthy, Lecturer in Audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any University for any other Diploma or Degree.

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CHAPTER - I

INTRODUCTION

"To bring the study of hearing out of the realm of the guesswork and to guide the medical treatment we need tests and above all, measurement of hearing".

- Hallowell Davis (1970)

The basic tests to find hearing sensitivity are the puretone tests and they remain as the basic are the puretone tests and they remain as the basic clinical tool for initiating differential diagnosis. Apart from finding the loss of hearing these pure tone tests also suggest the site of lesion. One of the most frequent problems posed by the clinician is to determine whether the patient's auditory response indicates conductive loss or sensorineural loss. In clinical audiometry, the measurement of cochlear reserve by bone conduction measurement is preferred.

Since atleast the early part of the 19^{th} century, bone conduction values were used diagnostically to differentiate conductive hearing loss and sensorineural hearing loss. Bone conduction thresholds.

provide the sensitivity of the auditory mechanism as a functional unit. The specific relationship between air conduction thresholds and bone conduction thresholds will provide us the magnitude of the hearing loss that can be attributed to impairment in the conductive mechanism and sensorineural mechanism.

During the past two decades as the result of the development of new surgical procedure, the measurement of bone conduction thresholds has gained clinical importance. The discrepancy between air conduction thresholds and bone conduction thresholds indicate the magnitude of the conductive component. Beyond a general classification of hearing loss as conductive hearing loss, the causal factors also can be inferred in some instances from closely examining the bone conduction configuration. Therefore audiometric technique used to assess hearing by bone conduction must be accurate, reliable and valid.

Inspite of the importance and extensive use of bone conduction measurements the clinical assessment has been plagued by numerous inherent problems. As investigators Carhart and Hayes (1950), Feldman (1961) have pointed out the reliability of measurement bone conduction thresholds has been widely mistrusted.

The validity and reliability of bone conduction results are limited by errors arising from several sources. Instrumentation, Psychophysical technique and mechanism itself are all potential sources of error. Though these variables are subject to control in laboratory and clinic it has not been utilized to a sufficient degree in the clinical setting. Since the basic principles of bone conduction audiometry are not clearly understood, the tests are often used inefficiently and inaccurately.

The measurement of bone conduction threshold is subject to error, because many variables affect the bone conduction thresholds. Some of the variables which affect bone conduction thresholds are: -

1. The force applied to the bone conduction vibrator on the skull
2. Pallesthesia
3. Intersubject variability of the mass of the head, the thickness and elasticity of the bones of the skull, the thickness of skin and tissue covering the mastoid bone etc.
4. The physical characteristics of bone conduction vibrators.
5. Placement of the bone conduction vibrators.

Above all the calibration of bone conduction vibrator is a major variable. Unfortunately there is no standard method of calibration of bone conduction vibrators. However the development of artificial mastoids has solved the problem to some extent. Davis and Goldstein (1970) mention that the calibration of the bone conduction vibrator is more difficult than that of the earphone and that the reference zero values are less clearly defined. The lack of reliable instrument for measuring the output of the bone conduction vibrator is a problem in calibration of bone conduction vibrators.

Testing bone conduction thresholds are further complicated by the problems of lateralization. Interaural attenuation for bone conduction is negligible irrespective of the placement of the vibrator on the skull. So getting response exclusively from the test ear is not possible for the bone conduction stimuli, unless we mask the nontest ear by adequate air conduction masker. But there are divergent opinions about when to mask, how much noise to be used etc. Central masking affects bone conduction thresholds. The problem of masking in bilateral conductive hearing loss is evident (Naunton's Dilemma). Another factor which complicates bone conduction

audiometry is that many patients have hearing loss so great that efforts to mask the contralateral ear are ineffective (Leden et al 1959 and Hood 1960). Wegel and Lane (1924) were among the first investigators to report changes in threshold on the test ear when masking tone delivered to nontest ear at low intensities. Denes and Naunton (1952) Zwislocki (1951) reported that the very pattern of hearing loss changes the quality and affectiveness of whitenoise. The problem is further complicated by the presence of air bone gap. Air bone gap in the masked ear increases the minimum masking by an amount equal to air bone gap. Air bone gap in the test ear reduces the maximum masking by amount equal to airbone gap.

Theoretically in pure conductive less the bone conduction thresholds should be normal. However the fact that the bone conduction sensitivity is not independent of the state of the middle ear has been indicated. In Otosclerosis, Carhart notch is seen. In cases of stapes fixation the measurement of bone conduction cannot be considered as an exact indication of the Cochlear reserve. Bone conduction thresholds can be altered by other external ear and/or middle ear impairments such as radical mastoidectomy (Bekesy 1939, and Tandorf 1966), Malleal

fixation (Goodhill 1966), Otitis media (Hulka 1941, Naunton and Fernandaz 1961, Carhart 1962, Huizing 1964, Dirks and Malmquist 1969). Producing a positive or negative change of air pressure in the external auditory meatus causes a change sensitivity for bone conduction as well as air conduction (Donald Dirks 1973). Lierle and Rager (1946) pointed out that a bone conduction curve is better than normal at low frequencies and poorer than normals at high frequencies is common in middle ear disease. It is unusual to find a patient with otisclerosis whose bone conduction thresholds are fully normal.

The precise measurement of bone conduction thresholds gives essential diagnostic cues and also the treatment depends on bone conduction measurements to a great extent. So accurate measurement of bone conduction sensitivity is demanded.

In order to overcome some of these problems other tests were developed to measure bone conduction sensitivity. Such of those tests are:-

1. Rainville technique (1955),
2. Modified Rainville test by Lightfoot (1960).
3. Sensorineural acuity level test by Jerger and Tillman (1960).
4. Brief tone audiometry as described by Miskolezy Fodor (1956).
5. Difference Limen test as described by Jerger (1953).

Even these tests are not free from demerits.

Tillman (1967) stated “Recognizing the limitations of bone conduction audiometry an attempt must be made to develop more precise methods for quantifying the sensorineural acuity”.

To the list of many methods of testing bone conduction, another test of bone conduction has been included by Vincent W. Byers (1974) which is called as “Conductive SISI Test”. This test is based on short increment sensitivity index (SISI) test. Here the hearing level (H.L.) at which hundred percent SISI score results is determined. Then the bone conduction threshold can be determined by using the formula:

Bc db = 60 db + Ac db – H.L. db (100% SISI) Application of the conductive SISI test is recommended when direct bone conduction measurements are not possible or when a bone conduction threshold is questionable.

The conductive SISI test has got the advantage over the conventional bone conduction measurements by overcoming some of the sources of errors.

To know whether the technique enables us to get a valid bone conduction threshold as attempt is made here

to verify the usefulness of this SISI test as a clinical tool is determining the bone conduction thresholds.

PURPOSE OF THE STUDY:

The purpose of the study is to test the following hypotheses:

1. All the ears without abnormal tone decay respond to 1 db increments when the energy reaching the cochlear is around 60 db.

2. The bone conduction thresholds obtained by conductive SISI test do not significantly differ from the bone conduction thresholds obtained by conventional bone conduction measurements in conductive hearing loss mixed hearing loss patients and sensorineural he aring less patients.

BRIEF PLAN TO THE STUDY:

Conductive SISI test and conventional bone conduction tests were administered to conductive hearing loss patients, Mixed hearing loss patients, sensorineural hearing loss patients and on ten normal subjects. All the measurements were made in a sound treated room using Beltone 15cx audiometer and Madsen portable type audiometer. The bone conduction thresholds by conductive SISI test and conventional method were

compared. Normal hearing subjects served as a criterion group to find the hearing level at which 100% SISI score is obtained. The test was administered at four test frequencies, viz: 500Hz, 1000 Hz, 2000 Hz and 4000 Hz.

DEFINITION OF SOME OF THE TERMS USED IN THE STUDY:

Carhart Notch: Carhart notch is the depression in bone conduction curve particularly at 2 KHz seen preoperatively in otosclerotic patients whose cochlear function is actually unimpaired.

Contral masking: Any use of masking – either in air conduction testing – even at low levels of intensity that evermasking is impossible will result in shifting the threshold of the test ear by 5 db at each frequency.

Inter-aural attenuation:

Interaural attenuation is the reduction in the physical intensity of an acoustical signal in passing from a transducer on one side of head to the opposite cochlea.

Minimum masking: Minimum masking may be defined as the masking level which is just sufficient to mask the test signal in the ear to which the masker is presented.

Maximum masking: Maximum masking is the masker level at the masked ear which is just insufficient to mask the test signal in the test ear.

Occlusion effect: The occlusion effect is an improvement in bone conduction thresholds as a result of partial or complete closure of the external auditory canal.

Pallesthesia: Response to the vibrator, with the vibration sense before the bone conduction threshold is stimulated in severe hearing loss patients for bone conduction sound.

CHAPTER - II

REVIEW OF LITERATURE

An excellent review of literature regarding the history of audiology is available in Translations of the Beltone Institute for hearing research No. 22, Jan. 1970 by Herald Feldmann. The review of literature concerned with this study is confined to bone conduction and short increment sensitivity index (SISI) test.

First in 1932 Bekesy demonstrated that the mode of the excitation of the cochlear receptors was same for both air conduction and bone conduction signals. In clinical audiometry bone conduction measurements are frequently used.

The early work of Carhart (1950) laid the foundation for the clinical utilization of bone conduction adutiometry. Bone conduction phenomenon is more complicated than air conduction. As a rule bone conduction thresholds reflect the function of the inner ear. A successful application of modern surgical technique require an accurate determination of the sound transmission and neural components of hearing loss (Studebaker 1962). The diagnostic strategy of audiology is directed primarily towards identifying the anatomical

location of impairments of hearing whether in the middle ear, the inner ear, the auditory nerve, the central nervous system or in some combination of two or more areas (Hallowel Davis 1970). Advice concerning the hearing aids, surgery for improvement of hearing and so on also depends in large part on a correct medical diagnosis. Comparison of air conduction and bone conduction thresholds is still the most definitive method for determining the degree and type of hearing loss (Ventry et al 1971). For differential diagnosis, as bone conduction thresholds are very important, the measurement of bone conduction must be reliable and valid. Inspite of its extensive use and importance the bone conduction measurement is not free from problems. The reliability of bone conduction measurements are questioned by many authors (Carhart and Hays 1950, Feldman 1961), Hughson Westlake stated that they held no belief for the accuracy of bone conduction tests.

In 1936 a committee, on methods of testing hearing by bone conduction outlined the difficulties of bone conduction audiometry as compared with air conduction testing.

The force applied to the bone conduction vibrator on the skull is one of the sources of error in bone

conduction measurements. The loudness with which certain sounds are heard by bone conduction will vary markedly as the pressure of the vibrator against the skull is varied from light to firm contact (Reger 1968).

As vibrator force is increased less energy is required to reach threshold by bone conduction. Harrish et al (1953) suggested that bone conduction receiver application force be standardized somewhere between 200 and 400 grams. Konig (1957) suggested that bone conduction receiver application force of 1000 grams is desirable in clinical audiometry. It is apparent from the study by Konig (1957) and Studebaker that application force significantly affects threshold and that it acts differentially across both frequency and vibrators. Dadson (1954) observed changes in mechanical impedance by varying the force of application. In the proposed international standards for bone conduction thresholds the suggested application force will be approximately 550 grams for a bone vibrator with a plane circular face area of 1.75 cm^2.

Bone conduction vibrator type is another variable in bone conduction measurements. Donald Dirks (1964) found that consistently grater electrical output from the automatic audiometer was needed to reach threshold with the grenade vibrator than with the hearing aid type

virbator. Sanders and Olsen (1964) and Wilber and Goodhill (1967) have also reported undesired harmonic distortion at low frequencies for a modern hearing aid type vibrator. Their data also indicate that the intensity output of the second and third harmonies grow disproportionately to the input. Nile (1968) found that surface area has no effect on threshold upto 2KHz. At 2KHz the threshold improved as the surface area was increased.

In bone conduction measurements Pallesthesia gives false results at low frequencies. When sound vibrations reach a sufficiently high intensity they may be perceived through the sense of touch. Barr (1955) described this as "Artifactual bone conduction". Herbert (1958) suggested that bone conduction thresholds at low frequencies are probably due to vibration an should not be misinterpreted. Bocca and Perani (1960) suggested that these low frequency bone conduction responses represent vestibular hearing. Portman and Portman (1961) Newby (1964) and Reger (1965) also indicated the presence of vibrotactile sensitivity at low frequencies. Since because the bone conduction vibrator is specifically designed to transmit mechanical vibrations to the mastoid

region the problem of vibrotactile stimulation becomes more acute in bone conduction audiometry (Boothroyd and Cawkweel 1970).

In audiograms of children with server sensorineural loss an apparent hearing loss of conductive type is often encountered primarily at 250 and 500 Hz. (Dayal 1972). Correlations between audiological vestibular and radiographic assessment indicate that the low frequency bone conduction threshold in these deaf children do not represent vestibular hearing but are vibrotactile sensations (Dayal 1972). The vibration sense is more sensitive to tones below 1000 Hz.

The mass of the head, the thickness, density and elasticity of the bones of the skull, the thickness of skin and tissue covering the mastoid bone and the degree of pneumatisation of the mastoid etc. are inter subject variability. In bone conduction measurements these affect the threshold of the individual. These factors are beyond the control of the examiner.

The physical characteristics of bone conduction vibrators are different from air conduction receivers and more problematic. More power must be delivered to

the bone conduction vibrator than to the air-conduction earphone in order to reach the threshold in normal ear. Consequently bone conduction hearing is limited. The frequency response of a commonly used hearing aid type vibrator is somewhat limited to the Speech frequency range.

For maximum sensitivity of the patient bone conduction vibrator has to be placed properly. There are various location to place the bone conduction vibrator. Although the vertex (Barany 1938, Studebaker 1962) of the skull and the teeth have been considered, the mastoid process and frontal bone have received the most attention as sites of placement for bone conduction measurements. The relative thresholds from the various cranical locations vary with frequency. It appears that cranial locations other than mastoid and frontal can produce good results. For several locations on the cranium the application of vibrator is difficult and uncomfortable for subjects.

Bekesy (1932) Barany (1938) and others have pointed out that mastoid process is a particularly unfavorable position because (1) shifts in the position of vibrator causes larger variation in mastoid placement. (2) Intersubject variation in skin and underlying tissue are greater at the mastoid.

(3) Mastoid aircells may affect bone conduction threshold. (4) At mastoid middle ear influence is more (5) The vibrator at the mastoid may come in contact with the outer ear and produce hearing by air conduction. Bekesy and Resenblith (1951) and Kirikae (1955) also agree that shifts of the oscillator on the mastoid grater than 3 cm in any direction affect the bone conduction threshold values. Feldman (1961) reported that mastoid seems to be least favorable site for bone conduction testing because at this site middle ear has its grater influence.

Naunton (1963) also points out that the mastoid placement too often leads both tester and patients to assume that the ear on the side of the bone conduction receiver is the one being stimulated when infact the interaural attenuation for bone conduction sound is near zero and both ears may be stimulated equally by a receiver on either mastoid.

In order to avoid the short comings of mastoid placement Bekesy (1932), Link and Zwislocki (1951), Hood (1957) have advocated the use of positions along the median sagital plane such as the forehead or vertex. Hirsh also indicated that it would be better to place on frontal rather than on mastoid. Donald Dirks (1964) too suggested frontal bone placement for reliable bone conduction information.

Bone conduction measurements from frontal placement gives test retest reliability (Bekesy 1932, Hart and Naunton (1961). Studebaker (1962) and Dirks (1964) did not show test retest differences. Frontal bone tissue is homogenous. Bekesy (1932) noted that the tip of the bone vibrator can be moved grater distances on the frontal bone than on the mastoid process without changing bone conduction thresholds. At forehead the bone density and skin thickness vary less, hair and cartilage do not interfere and air conduction leakage through the vibrator is less of a problem, there is a reduction of localization by virtue of suggestion.

At frontal placement the participation of middle ear is less. Barany's (1938) theory states that bone conduction threshold measured from positions on the median sagital plane such as the forehead are less affected by changes in the middle ear than are threshold measured from the mastoid. Link and Zwislocki (1951) using patients with middle ear pathology found the pathology to exert less influence upon bone conduction from forehead than it does in mastoid placement. Studebaker's (1962) study on conductive loss shows that the frontal bone conduction thresholds show less hearing loss than at the mastoid process. At frontal placement intersubject variability is less. Study by Lipply et al (1966) indicate that improved bone

conduction thresholds particularly at 500 Hz and 1000 Hz when the bone oscillator was placed on the central incisors rather than the mastoid area. Dirks and Malinquist (1969) demonstrated less hearing loss from frontal placement.

Inspite of their advantages frontal placement method is not widely used because of some demerits. Studies by Pohlman and Kranz (1926), Dean (1930), Bekesy (1939), Link and Zwislocki (1951) and Studebaker (1962) show that the thresholds at forehead are higher at all frequencies than those obtained at mastoid. Vertex thresholds are also higher than the mastoid thresholds. The study by Feldman (1961) shows that the thresholds at frontal placement is 10 db higher than the mastoid process. So that range of measurable hearing is reduced when testing at frontal because of power handling limitations of commercially avialble virbators. Naunton and Fernandaz (1961) reported considerable change in threshold at the frontal bone in 3 cases of otitis media. They observed an improvement in bone conduction thresholds in the low frequencies but a reduction around 2000 Hz.

Studebaker (1962) reported mastoid forehead difference values of 14.8 db at 0.5 KHz, 9.7 db at 1KHz and

9.4 db at 2 KHz. These values were essentially confirmed by Hoops and Curry (1963) and Barber and Rose (1969). Donald Dirks (1964) and Tillman indicated that the magnitude of the difference between the frontal and mastoid threshold decreased as the frequency increased, With frontal placement masking must always be presented.

Calibration of the bone conduction vibrator is another variable. The calibration of bone conduction receiver has been a problem to the clinical audiologists for years. Baranek (1949) suggested a loudness balance procedure. Such procedure are (1) fraught with the problem of masking one ear. (2) The need to remove the earphone from the test ear in order to avoid occlusion effect for frequencies 1000Hz and loss when bone conduction delivers comparison tone. Loudness balancing is a difficult job particularly if there is silent interval between the two stimuli to be compared as would be unavoidable with the necessity of removing the earphone when listening to the bone conduction stimuli. The AMA (American Medical Association) and Hedgecock (1961) prepared the comparison of air conduction and bone conduction thresholds on normal hearing persons for calibration. Reach and Reach (1951) and Carhart (1956) advocated the testing of persons with pure sensorineural hearing loss to compare air conduction

and bone conduction thresholds agreement. These methods are based on the assumption that persons who do not have conductive hearing impairment will have equal thresholds levels for air conduction and bone conduction.

Biological calibration may not give good results because inter-subject variability and test retest differences are larger (Wilber and GoodHill 1967). Because of this problem in using real ear comparison, artificial mastoid was used to have precise measurements. Although there have been a number of artificial mastoids, no artificial device for the measurement of the vibratory output of an audiometer bone vibrator has been standardized (Hawly 1979, Carlisle 1944, Greibach 1946, Carlisle and Pearson 1951). Greibach (1946) encountered difficulty in finding a material that would give a faithful simulation of bone, the stiffness, and the resistance of human mastoid. Reach (1951) used an artificial mastoid with a plastic viscoelastic pad and found difference in day to day measurements as great as 9 db. The results of the study by Sanders and Olsen (1964) by using Weiss artificial mastoid indicated that reliability for day to day measurements was good and the artificial material had good stability over an extended period of time. Reach and Carchart (1956) said “We lack a standard procedure

whereby the physicist can specify for us the vibrational output representing the bone conduction norms". There is no reliable and objective method for specifying the vibrational output of bone conduction testing system. No artificial mastoid is well standardized. Reference values are less clearly defined for bone conduction vibrators.

Lateralization make the bone conduction measurement still more complex. Problem of lateralization is a difficult one to resolve in bone conduction testing. In 1834 Weber described only the phenomenon of lateralization of bone conduction on the occlusion of external auditory meatus. Weille and Gargane (1953) suggested that interaural attenuation for bone conduction may be frequency dependent ranging from 0 to 20 db. Studies by Zwislocki (1953) Littler, Knight and Strange (1952) Lushor and konig (1955), Studebaker (1962) have shown that the transmission loss across the skull will vary with the earphone used and Whether or not the contralateral ear is occluded. Hood (1957) and Feldman (1961) considered interaural attenuation for bone conduction to be essentially negligible. So irrespective of the placement of the vibrator both the cochleas will be stimulated. Experimental data by Sedee (1957), Green (1962) and Naunton and Elpern (1964) shows that interaural

phase difference from a factor that can contribute to the lateralization of bone conduction into the poor ear in conductive deafness. But still the phenomena is not well explained. Study by Huizing (1970) shows that in cases of Bilateral asymmetrical conductive deafness bone conduction lateralization is affected when the poor ear has been transformed by stapes surgery into better ear. Because of this negligible interaural attenuation for bone conduction, the obtained threshold cannot be attributed solely to the test ear with certain. Since the vibrator transmits the energy to the whole skull as has been demonstrated by Bekesy (1932), Bareny (1938) and Kirikae (1959) both ears are stimulated to approximately the same extent irrespective of the placement of the vibrator.

So it becomes necessary to mask the nontest ear while doing bone conduction testing. The most important disadvantage of bone conduction audiometry is the need to mask the nontest ear. There remains some disagreement as to the appropriate signs and indications for the use of masking in the nontest ear. The technique of masking has a strong effect on the accuracy and the range of the test.

The efficiency of masking depends upon the frequency spectrum of the masking stimulus (Feldman 1961).

Zwislocki (1951) has observed three basic problems involved in the use of any broad spectrum, Masking noise (1) To obtain a sufficient level of effective masking the loudness is frequently annoying and distracting. (2) Only a small portion of the total spectrum of the noise is actually providing the masking. (3) The ear not being equally sensitive to all the frequencies in the spectrum is not as effectively masking at each frequency by identical intensity levels of the masking stimuli. Selecting the narrow band stimuli is a more efficient means of providing the desired selective activation of the cochlea with a minimum loudness. Donald Dirks says that the common clinical problems of the nonavailability of sufficient masking in the nontest ear is partially allevi ated by the use of narrow band masking. Noise in the non test ear influences the threshold of the test ear.

Wegel and Lane (1924), Carhart (1950), Zwislocki (1953), Ingham (1957), Sherrick and Mangabeira – Albertanz (1961), Studebaker (1962) and Triesman (1963) have reported shifts in threshold for bone conduction due to masking in contralateral ear. As the level of noise in the non test ear increases there is a small but gradual shift in the threshold of the test ear.

It is due to central masking. A corrective factor may have to be introduced when thresholds are measured with higher level of noise in the opposite ear as suggested by Donald Dirks (1964).

The clinician usually encounters the problems of overmasking while testing bone conduction and it is particularly evident while testing conductive impairment. The attenuation produced by conductive barrier and lateralization force the use of more intense masking which results in binaural stimulation by vibrating the skull with a stimulus that originated as an air conduction stimuli. Ralph Nauton (1960) states, “there are theoretical grounds for believing that in testing the hearing of some subjects with bilateral conductive deafness it is impossible adequately to mask the hearing of the opposite ear without at the same time masking the hearing of the test ear”. In bilateral conductive hearing loss optimum masking is not possible (Naunton and Dilemma).

Another problem in masking is that many patients have hearing loss so great that efforts to mask the contralateral ear are ineffective (Leden et al 1959 and Hood 1960). The configuration of the hearing loss itself changes the quality and effectiveness of whitenoise.

The presence of air bone gap influences the amount of masking. Air bone gap in the masked ear increases the minimum masking by an amount equal to air bone gap. Air bone gap in the test ear reduces the maximum masking by amount equal to air bone gap.

The problem is further complicated by the phenomenon of conclusion effect. Kelley and Reger (1937), Martin and Schlieffer (1969) and Jerome Liebman (1968) found that occlusion effect is frequency dependent. In middle ear pathologies occlusion effect is eliminated. Occlusion effect vary according to Pathology. Feldman (1961) and, Elpern and Naunton (1963) found that the intersubject variability of occlusion effect is very high. Inter –test variability was also reported to be larger by Elpern and Naunton (1963). The occlusion of the ear under test introduces new and easily controlleable variables.

Though we expect normal bone conduction thresholds in conductive loss subjects, in practice we see that the bone conduction thresholds is not independent of middle ear status. There is clear increase of bone conduction loss with increasing duration of middle ear disease. Among seven specific components which Tondorf identified as contributing to the total bone conduction response four

(middle ear inertia, middle ear cavity compliance, round window pressure release, oval window pressure release) were directly related to the participation of the middle ear. Tondorf (1966) suggests that middle ear contribution is not confined to low frequencies as classical theories suggest. The concept that stapes fixation eliminates inertial bone conduction is rejected because in clinic high frequency loss is seen.

Patients with otosclerosis who possess normal cochlear and neural functions do not yield completely normal bone conduction audiograms. The work of Carhart (1950) and McConnel (1950) suggest that the typical reduction in sensitivity in stapes fixation cases is 5 db at 500 Hz, 10 db at 1000 Hz, 15 db at 2000 Hz and 5 db at 4000 Hz. This depression in threshold may result from mechanical factors rather than from sensorineural involvement. This is known as Carhart notch. The types of configuration for stapes fixation and other middle ear pathologies helps in differential diagnosis. Evidences suggest the following findings:

1. When stapes is fixed the bone conduction responses at the frontal and mastoid

process are altered in a similar manner (Donald Dirks and Malmquist 1969).

2. If the oscicular chain is partially eliminated by a radical mastoidectomy the thresholds for bone conduction at both sites are reduced maximally around 2000 Hz. The reduction is notas large for measurements at the mastoid.

The amount of bone conduction loss depends upon the degree of fixation. Since the oscicular chain has a resonant point near 2 KHz (Green 1962) in man, the maximal loss should be found in this frequency area when the oscicular chain is fixed. Tadorf's evidence suggest that it is essentially the missing oscicular inertial component that determines the frequency value of the point of maximal loss when the middle ear is amputated. The post surgical bone conduction thresholds of such cases are in closer agreement than are their pre-surgical ones to the status of their cochlear sensitivity as estimated from other forms of evidence. Donald Dirks (1972) reported that the improvement in otosclerosis is due to the mechanical changes in the oscicular system and not to cochlear modification. The amount of improvement in the post-operative bone conduction levels correspond closely to the average shifts in the bone conduction response due to stapedial fixation as reported by Carhart.

Tondorf demonstrated elevation in the bone conduction responses in various species of animals following removal of middle ear structures or immobilization of Tympanic membrane.

Bekesy (1939) Tondorf (1966) have each described a case in which bone conduction threshold were altered following radical mastoidectomy. Hulka (1941) found some high tone sensorineural hearing loss and gain in the low frequency in middle ear pathology patients. Palva and Ojala (1955) however did not find a shift in bone conduction thresholds in Otitis media patients. Gardenghi (1955) found that in his study with chronic purulent otitis media patients, 44% had evidence of cochlear lesion. Huizing (1960) also reported bone conduction threshold changes in patients with otitis media tubotympanities and chronic inflammatory processes. Naunton and Fernadez (1961) reported an improvement in bone conduction thresholds at the low frequencies and a slight loss in the high frequencies when the fluid present in the ears of the bilateral secretory otitis media patients. Studebaker's (1962) results showed only a small difference between thresholds at frontal bone and the mastoid process on a group of various conductive lesions and both sets of thresholds were depressed comparing with normals.

Blwshtein (1963) reported that 37.5% of his patients with chronic otitis media were found to have some loss of cochlear function. Some alterations in the middle ear similarly affect mastoid and frontal bone conduction thresholds (Donald Dirks and Malmquist 1969).

Goodhill (1955) reported a carhart type notch extending into the higher frequencies for a patient with a surgically confirmed mallealar fixation.

With normal hearing people it has been demonstrated that bone conduction responses can be altered experimentally by (1) air pressure changes in the external auditory canal (Fowler 1920, Barany 1938, Loch 1942, Kirikae 1959, Allen and Fernandaza 1960, Huizing 1960). (2) Loading of the tympanic membrane (Barany 1938, Rytzner 1954, Kirikae 1959, Allen and Fernandaz 1960, Abu-Jaudeh 1964, Brinkman, Marrens & Lolk 1965), and (3) The occlusion of external auditory canal (Pohlman & Kranz 1926, Bekesy 1932, Kelley and Reger 1937, Watson and Gales 1943 et al).

Substantial data have accumulated demonstrating that bone conduction thresholds do not represent a pure

estimate of cochlear reserve in conductive hearing loss cases. Donald Dirks (1972) reports that this is a short-coming.

Since because accurate measurement of bone conduction sensitivity is extremely needed in clinical audiometry and also because the conventional bone conduction audiometry did not satisfy the conditions, other alternate methods were developed for obtaining the information, which bone conduction audiometry can yield. Certain very positive and productive steps have been taken during the past years to solve some of the problems of conventional bone conduction measurements.

Jerger (1953) described difference Limen technique for establishing sensorineural acuity. But it awaits better standardization. So this test was not used extensively.

In 1955 a modified bone conduction test was proposed by Rainville. In this technique, comparisons were made between the level of noise required to mask an air conducted puretone when the masking noise was presented (a) via air conduction and (b) via a bone conduction vibrator. Rainville's method provided to be a somewhat cumbersome clinical tool. It is rather tedious to perform and requires instrumentation that allows a careful

measurement and comparison of air conduction noise. Problems of instrumentation and the lack of control over the occlusion effect are the disadvantages of this method. Also, a possibility of error may arise from auditory adaptation occurring during the time required to mask the threshold tone. Goldstein, Hayes and Peterson (1962) report that for the conductive and mixed hearing loss groups the bone conduction thresholds obtained by conventional and Rainville techniques were highly similar at 2 KHz and 4 KHz but significantly different at 250 Hz and 500 Hz. But for sensorineural hearing loss group subjects' thresholds by both the methods approximated at all levels.

Lightfoot in 1960 modified Rainville technique. Jerger and Tillman (1960) also modified this technique which is known as Sensorineural Acuity Level (SAL) test. They measured the threshold shifts for puretones produced by an intense thermal noise introduced to the forehead by bone conduction. The threshold shift of the patients with impaired hearing was then subtracted from the shift established an subjects with normal hearing. The difference between these two are called sensorineuraul acuity level. The basic premise of this technique is that the amount of air conduction thresholds shift at a given frequency will be directly proportional to the sensorineural acuity at that frequency for a know amount of bone conduction noise.

The advantage of SAL technique is that it eliminates danger of ignoring unsuspected shadow responses (Carhart 1962). Carhart (1962) reported that the counterpart of the Carhart notch appears in SAL test results. Serious concern as to the validity of the SAL test as a method for quantifying sensorineural acuity have been raised by Naunton and Fernandaz (1961), Goldstein et al (1962) Tillman (1963) and Martin and Bailey (1964).

Tillman (1963) evaluated the SAL test and found discrepancies between the bone conduction thresholds by this method and by conventional method for subjects with sensorineural loss and conductive loss.

On the basis of his evaluation Tillman (1963) indicated that the SAL technique could not be considered as an adequate substitute for properly applied bone conduction tests, Matkin and Olsen (1971) also say that SAL approach cannot be considered as a substitute for bone conduction tests. However Jerger (1965) critically evaluated SAL test and has found that it is clinically useful provided the influence of occlusion effect is taken into account.

Brief tone audiometry ad described by Miskolezy Fodor (1956) is another technique designed to determine

the status of sensorineural mechanism. But its use is limited to identify the site of lesion.

As stated by Tillman in 1967 attempts were made to develop more precise methods for quantifying the sensorineural acuity. In 1974 Vincent W. Byers used the SISI test to find the bone conduction thresholds.

Jerger, Shedd and Harford (1959) introduction SISI test, a test technique designed to differentiate subjects who were able to detect very small amplitude changes presented periodically in a puretone signal. Basically the test consists of superimposing brief 1 db increments on a sustained tone of the same frequency at an intensity level of 20 db above the threshold of the person under study. The score derived from this test reflects the percentage of 1 db increments heard by the listener. The SISI test is relatively simple technique to administer and not a difficult task to perform by the subject. The basic premise of the SISI test is that an ear's ability to detect smaller increments than usual in sound intensity is pathognomonic of end organ dysfunction.

Jerger (1962) mentioned that his experience indicated scores between 0% and 20% for those with normal

hearing, with conductive loss and scores between 60% and 100% (at frequencies above 1 KHz) for patients with cochlear pathology. Average normal ear is least sensitivity to 1 db increments at 20 db SL.

Since the description of SISI test by Jerger (1959) the investigation of sensitivity of ear to changes in intensity has found wide application in the topical diagnosis of hearing loss. Several studies are now available on the reliability of SISI test and on a range of variables which are of significance for the results of SISI test. Harris (1963) reports subjects responding to the same kind of stimulus as used in the Steven's study (instrumental pure tone) were able to hear increasingly smaller increments as the sensation level was raised.

Yantis and Decker (1964) did a detailed study on the various aspects of SISI test and found that sensitivity to amplitude even of the small size 1 db tend to increase in the average normal ear with increasing frequency. They found SISI scores becomes progressively greater with increased intensity of the automatic tone pulse and the average normal ear is least sensitive to 1 db increment.

Relatively consistent increase in average SISI score was found by them for each of the intensity categories as a function of higher frequency of the test tone. Their study indicates that a few normal hearing individuals do have relatively keen sensitivity to the small increment used in the test. They found a tendency of SISI scores to cluster at extremes of the continuum and concluded that the test may be safely reduced to ten increments in many cases.

Blegvad (1966) noted an increase in the SISI values with the frequency increasing from 250 Hz to 4000 Hz, when the sensation level were 10 and 20 db. But at 40 db SL the scores were grossly independent of frequency. They noted that increased percentage for SISI test were obtained from the test ear if the contralateral ear was masked, particularly at high frequencies. This finding was confirmed by Ostethammel et al (1970). The study by Pushpa (1974) shows that contralateral masking noise has facilitating influence on the SISI scores. Sanders (1966) from his study concluded that the SISI test should be continued with the 1 db increment originally proposed.

The results of the study by Swisher, Stephens and Doehring (1966) indicated that the SISI score is influenced by both the hearing threshold level of the carrier tone and normal variability in differential sensitivity. Swisher, Stephens and Doehring (1966) studying the effects of increasing sensation level on SISI scores suggested that the SISI test might be interpreted as an indirect measure of bone conduction threshold. Swisher (1966) and Swisher et al (1966) also showed that normal and non adapting sensorineural impaired ears discriminated a signal of 1 db or less quality well at equivalent SPL.

The study by Young and Harbert (1967) showe d that at SPL's of 45 db and above every normal subject showed a SISI score of 65% or higher for all frequencies. There were not absolute difference, in the pattern of SISI score for different frequencies. At equivalent intensities from 60 to 120 db SPL the affected and control ears behaved almost identically obtaining scores of 70% or higher. The majority of control ears obtained scores of 40% or less at intensity levels between 45 and 60 db. In general a high SISI score occurs when atleast 60 db SPL reaches the inner ear. Intensity level reaching the inner ear is the determining factor in perception of the 1 db

increment. If the inner ear receives an audible signal of 60 db SPL or higher there is essentially no difference in the performance on the SISI test of ears with normal hearing, conductive pathology or non adapting sensorineural hearing loss. If the residual signal is greater than 60 db SPL after the conductive barrier is subtracted the conductively impaired ear behaves like a normal ear. In conductive and mixed deafness the conductive barrier in db should be added to the 70 db SPL test signal to obtain a positive score.

According to Blegvad and Terkildsen (1967) there can be an artificial improvement in the SISI score at 1 KHz, 2 KHz and 4 KHz and a decrease in the lower frequencies when masking is used in opposite ear.

Study by Belgvad and Terkildsen (1967) Young and Harbert (1967) found that SISI scores were dependent upon the SPL at the cochlea. Frequency has been found to affect SISI scores with higher frequencies yielding higher SISI scores. (Harford 1967). Young and Harbert (1967) suggested as an alternative that the steady tone be presented at a standard SPL of 70 db or higher if necessary for audibility. The employment of ten rather than twenty test increments has been recommended for selected cases by Harford (1967); Owens (1965), and Griffing and Tuck (1963).

Young and Harbert in their study in 1967 found SISI scores for normals run at frequencies 0.25 KHz to 4 KHz at 30 -100 db SPL. At SPL's of 45 and above every normal subject showed a SISI score of 65% or higher for all frequencies. There were no observable differences in the pattern of SISI score for different frequencies. At equivalent intensities from 60 to 120 db SPL the affected the control ears behaved almost identically obtaining scores of 70% or higher. The majority of control ears obtained scores of 40% or less at intensity levels between 45 and 60 dh. In general a high SISI score occurs when alteast 60 db SPL reaches the inner ear. SISI scores for abnormally adapting ears are close to 0% for all tested intensities from 40 to 125 db. Intensity level reaching cochlea is determining factor in perception of the 1 db increment. Conductive barrier in conductive loss patients reduced the signal reaching the inner ear. They noted that after the conductive barrier (AC TH-BC TH) was overcome a high SISI score generally occurred when 60 db sound pressure reached the inner ear.

The significance of the study by Young and Wenner is the abrupt change in the SISI score as the function of the SN ratio. The change in SISI scores near 0% to near 100% is as dramatic as that which occurs when the intensity changed from 40 to 50 db SPL in the quiet for trained listeners.

Harbert, Young and Weiss (1969) report that recruiting ears and normal ears perceive intensity increments of equal size at equivalent SPL. In their study low SISI scores occurred when the subject received signal at 55 db SPL or below. Hardford (1965) and Harbert, Young and Weiss (1969) emphasize that SPL rather than SL is the important parameter in determining the score value. When the percentage scores in conductively deafened ears are plotted after subtracting the conductive barrier these ears show an abrupt change in SISI scores at 60 db. Trained normal listeners notice this change at 50 db SPL. It appears likely that subjects who undergo repeated testing or are acute observers may also respond with high scores at this level and above.

Study by Frederic Martin and Salas (1970) showed that normal ears did not give high scores on the SISI test when tested at the same loudness as pathological ears. They found that when normal ears receive the same SPL as 20 db above thresholds in a cochlear impaired ear, equal and positive SISI scores results. The results suggested that it is not the subjective loudness of the carrier tone which produces high SISI scores in cochlear impaired ears but rather high SPL's. As the SPL increased in the normal ears of the subjects, the SISI scores also

increased. As the amount of tone decay increased the SISI score decreased in bad ear. Their study shows that high SISI scores begin to occur in the good ear somewhere between 55 and 65 db SPL. Subjective loudness does not explain performance on the SISI test. The low scores in conductive loss patient is due to the fact that the level has been attenuated a significant amount by his external and/or middle ear.

Study by Rubinstein et al (1970) report that the sensitivity of the ear to small increments of intensity also depends upon the ongoing level of the carrier tone. The higher the sensation level higher the responses. The differentiation of normal from abnormal results will depend upon (1) the magnitude of the increment (2) the SL of the carrier tone and (3) the percentage of correct response. Various combination of these three variables will help in differentiation.

Martin's study (1970) shows that when the SISI test was performed at the same SPL in the normal ear as 20 db SL in pathological ear scores were identical in both the normal and affected ear (Cochlear impaired ear).

Sandra Katinsky et al (1972) report that their clinical experience has shown and recent research has substantiated (Herbert et al 1969) that positive SISI scores rarely result if the test signal presentation is less than 50 to 60 db SPL. Pushpa (1974) in her study found that majority of normals obtained 100% SISI score at 65 db HL.

It is reported that SISI scores increased with practice and increased SISI scores persisted after 3 weeks of no practice, increased SISI scores were not a function of frequency by Fulton and Spradlin.

In 1974, Vincent W. Byers described "Conductive SISI test", an indirect procedure to estimate bone conduction thresholds for middle ear pathology patients. A series of SISI tests are run beginning at 20 db SL and increasing in 10 db SL steps until a 100% SISI score is obtained. They gave the following equation to predict the bone conduction thresholds.

BC db = 60 db + Air conduction

(db) - H.L. db (100% SISI)

The results of 25 conductive SISI tests on a conductive hearing loss group indicate that the equation approximates

the measured bone conduction threshold. They report that there was no statistical difference between the predicted thresholds and measured bone conduction thresholds for the group.

CHAPTER – III

METHODOLGY

PROCEDURE:

This study comprises the following parts:

1. Obtaining pure tone air conduction and bone conduction thresholds for all the subjects.

2. To find the hearing level at which 100% SISI results in normal hearing subjects.

3. To find the Hearing level at which 100% SISI results and to calculate the bone conduction threshold as suggested by Vincent W. Byers (1974) in clinical group subjects (conductive hearing loss, mixed hearing loss and sensorineural hearing loss).

The frequencies tested were 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz.

Subjects: For this study two groups of subjects were

chosen. The first group consisted of ten normal hearing voluntary subjects. They had the thresholds of 20 db HL (ISO 1964) or less than 20 db HL (ISO 1964) in both the ears. The second group included 25 conductive hearing loss subjects of various pathological conditions such as C.S.O.M., serous otitis media, Dry performance, Otosclerosis, Oscicular rupture, Tympanosclerosis etc. 6 mixed hearing loss subjects and 3 sensorineural hearing loss subjects. Totally 43 conductive hearing loss ears, 9 mixed hearing loss ears and 4 sensorineural hearing loss ears were tested in the second group. Depending upon the involvement both ears or one ear was selected for testing. Subjects' age ranged from 15 yrs to 57 yrs with a mean age of 29-29 yrs. In normal hearing group all the subjects were males. In clinical group twenty eight males and five females were tested.

Equipment and Test Environment:

A calibrated Beltone 15 cx model clinical audiometer to get air conduction thresholds and to administer SISI test and a calibrated Madsen Portable Audiometer

TEN 60 to get bone conduction thresholds were used for the entire study. With Beltone 15 cx clinical audiometer a TDH 39 earphone mounted in MX 41/AR cushion was used. With Madsen Portable Audiometer Denmark A 39 bone vibrator was used. Both the audiometers were calibrated using Bruel & Kjaer instruments. Block diagram for calibration is given in the appendix. The output levels for air conduction measurements for Beltone 15 cx audiometer are given below:

Audiometer earphone output date for the (Rt) earphone of the Beltone 15 cx audiometer.

Audiometer: Beltone 15 cx	Artificial ear: B & K type 4152
Earphone Type: TDH 39	Microphone: B & K 4144
Cushion Type: MX 41/AR	A.F. Analyzer: B & K Type 2107

For table see next page.

Date	Frequency in Hz	Input level	Reference in db SPL	Expected output in db SPL	Obtained output in db SPL
10.12.74	500	60 db HL	11.0	71.0	72.50
	1000	60 db HL	6.5	66.5	69.75
	2000	60 db HL	8.5	68.5	70.00
	4000	60 db HL	9.0	69.0	75.00
21.2. 75	500	60 db HL	11.0	71.0	72.0
	1000	60 db HL	6.5	66.5	68.50
	2000	60 db HL	8.5	68.5	62.25
	4000	60 db HL	9.0	69.0	75.25

Audiometer output data for the Lt. earphone of the Beltone 15 cx audiometer.

Audiometer: Beltone 15 cx

Artificial ear: B & K type 4152

Earphone Type: TDH 39

Microphone: B & K 4144

Cushion Type: MX 41/A

A.F. Analyzer: B & K Type 2107

Date	Frequency in Hz	Input level	Reference in db SPL	Expected output in db SPL	Obtained output in db SPL
10.12.74	500	60 db HL	11.0	71.0	69.50
	1000	60 db HL	6.5	66.5	65.00
	2000	60 db HL	8.5	68.5	64.25
	4000	60 db HL	9.0	69.0	71.75
21.2. 75	500	60 db HL	11.0	71.0	69.0
	1000	60 db HL	6.5	66.5	69.0
	2000	60 db HL	8.5	68.5	68.5
	4000	60 db HL	9.0	69.0	74.5

The linearity of the hearing loss dial was checked and found to be in order. The output values for bone conduction vibrator are given below.

Audiometer: Madsen Artificial mastoid: B & K type 4930

Bone vibrator type: Denmark A 39 A.F. Analyzers B & K Type 2107

Date	Frequency in Hz	Input Hearing level	Expected output	Obtained output	Correction
10.12.74	500	40 db HL	72 db SPL	62 db SPL	-10 db
10.12.74	1000	40 db HL	58 db SPL	62.5 db SPL	+5 db
10.12.74	2000	40 db HL	51 db SPL	60.5 db SPL	+10 db
10.12.74	4000	40 db HL	42 db SPL	38.0 db SPL	+5 db

Necessary correction was applied to the obtained audiometric values wherever needed. The SISI unit of Beltone 15 cx audiometer was calibrated using Bruel and Kjaer artificial ear type 4152, condenser microphone No. 4144, Bruel and Kjaer level recorder Type 2305, Bruel and Kjaer Frequency Analyzer Type 2107, in terms of increment size, raise time, decay time and duration time. It was found to have the following values: increment size 1 db, raise time: 133m sec. decay time 133 m sec. and duration time 266 m seconds. The interval between successive increments was 6 seconds. The calibration was checked at regular intervals.

All the testing were done in a sound treated room. SPL values inside the audiometric room are given below:

Noise levels in the audiometric rooms measured in Octaves.

Serial No.	**Octave bands in HZ**	**Maximum allowable noise level in db SPL**	**Noise level in the room in db SPL**
1.	75 – 150	31	18
2.	150 – 300	25	17
3.	300 – 600	26	15
4.	600 – 1200	30	9
5.	1200 – 2400	38	11
6.	2400 – 4800	51	10.5
7.	4800 – 9600	51	10

The noise levels in the audiometric room were satisfactory according to proposed standard (ISO 1964) specifications. (Martin Hirschorn 1967).

TEST PROCEDURE:

For all the subjects pure tone air conduction thresholds, bone conduction thresholds and the hearing level at which 100% SISI score results were found out.

All the subjects in clinical group had Otological examination before testing. The method of threshold determination was based on the suggestions of Carhart and Jerger (1959) that determining thresholds by an ascending method. The testing was done in the order of 1000 Hz, 2000 Hz, 4000 Hz and 500 Hz. In normals, in conductive hearing loss, and in mixed hearing loss subjects the SISI test was started at 40 db above the conduction barrier. In sensorineural hearing loss patients the test was started at 10db SPL. Whenever the subjects failed to give response for 1 db increments the intensity of the carrier tone was raised in 5 db steps. The hearing level at which the subject gives 100% SISI score was found out. The contralateral ear was masked whenever necessary. For all the subjects ten 1 db increments were presented as suggested by Yantis and Decker (1964). After getting air conduction thresholds and the hearing level at which 100% SISI was obtained the bone conduction thresholds were calculated by using the formula.

BC TH = 60 db + air conduction (db)

- Hearing level db (100% SISI)

Bone conduction thresholds obtained by conductive SISI test were compared with conventional bone conduction thresholds.

Instructions for pure tone audiometry:

"You are going to hear tone in your ear through the earphone or through bone conduction vibrator. At a time, only one ear will be tested. Whenever you hear the tone raise your finger. If your hear in right ear raise your right hand finger, if you hear in left ear, raise your left hand finger. Keep your finger raised as long as you hear the tone. The moment you hear the tone raise your finger and the moment you don't hear the tone drop your finger. Even for faint sounds you have to respond. Listen carefully".

In SISI test administration, first, five practice events of 5 db, 4 db, 3 db, 2 db and 1 db increments were given in order to familiarize the subjects. Then ten 1 db increments were presented superimposed on a sustained tone. Randomly a control event of 5 db or 0 db was given depending upon the subject's response. This enabled to check false positive or false negative responses. The hearing level at which the subjects could detect all the ten increments were found out.

Instructions for SISI test:

"You will hear a continuous tone in your ear. You are required to keep your finger raised for the presence of the tone. Sometimes there will be jumps in the loudness. The jump even may be a small one, whenever you hear the jump in the loudness flicker your finger. If you don't hear the continuous tone drops your finger".

To check the reliability, tests were repeated on five normal subjects on different days.

CHAPTER – IV

RESULTS AND DISCUSSION

The following are the results obtained in verifying the previously stated two hypothesis. The experimental results are divided into two parts: The first part of the study deals with analyzing twenty normal ears' response for 1 db increments of SISI test. In the second part of the study both conductive SISI test results and bone conduction test results obtained on clinical group subjects (conductive hearing loss, Mixed hearing loss and sensorineural hearing loss) are analyzed.

In the first part, to verify the hypothesis – "All the ears without abnormal tone decay respond to 1 db increments when the energy reaching the cochlea is around 60 db", twenty ears of ten normal hearing subjects were tested by SISI test. Majority of them were naïve listeners. The hearing level at which the subjects responds to all the ten 1 db increments (100% SISI) was found out for all the ten subjects.

Table I give the mean air conduction threshold, range of hearing levels for 100% SISI and mean hearing

level at which 100% SISI score was obtained in normal hearing subjects. 100% SISI score was observed in normal hearing subjects at mean value of 65.12 db HL.

TABLE – I

Frequency	**Mean air-conduction Threshold**	**The range of hearing levels for 100% SISI**	**Mean hearing levels for 100% SISI**
500 Hz	6.25 db HL	55 – 80 db HL	67. 0 db HL
1000 Hz	6.50 db HL	55 – 75 db HL	66.0 db HL
2000 Hz	6.75 db HL	55 – 75 db HL	64.0 db HL
4000 Hz	5.50 db HL	50 – 70 db HL	63.5 db HL

Young and Harbert (1967) reported that in general a high SISI score occurs when atleast 60 db SPL reaches the inner ear. Intensity level reaching the inner ear is the determining factor in perception of the 1 db increments. Harbert Young and Weiss (1967) reported that, in normals nearly 100% SISI score occurs at 60 db SPL and also that, low SISI scores occurred when the subjects received signal at 55 db SPL or below. They have reported

that trained normal listeners, acute observes an subjects who undergo repeated testing also may show high scores at 50 db SPL. Study by Martin and Salas (1970) also shows that high SISI scores began to occur in normal ears somewhere between 55 and 65 db SPL. Pushpa (1974) has observed that 75% of normal hearing subjects obtained 100% SISI scores at 65 db HL and the rest obtained 100% SISI scores within 80 db HL. The results of this study closely agrees with the above mentioned studies indicating that in normals an average of 65.12 db HL is required to get a 100% SISI score. Below 55 db HL at 500 Hz, 1000 Hz and 2000 Hz and below 50 db HL at 4000 Hz no subjects scored 100% SISI score.

In second part of the study the null hypothesis "The bone conduction thresholds obtained by conductive SISI test do not significantly differ from the bone conduction thresholds obtained by conventional bone conduction measurements in conductive hearing loss, mixed hearing loss and sensorineural hearing loss patients" is verified. 43 conductive hearing loss ears, 9 mixed hearing loss ears and 4 sensorineural hearing loss ears were tested to get bone conduction thresholds by both conductive SISI test and conventional method. The obtained results are analyzed by dividing into the following groups:

a) Total clinical group
   (Conductive hearing loss, mixed hearing loss and sensorineural hearing loss),
b) Conductive hearing loss group,
c) Mixed hearing loss group, and
d) Sensorineural hearing loss group.

TOTAL CLINICAL GROUP:

Table 2 shows the number of ears (Clinical group) tested at different frequencies.

TABLE – 2

Frequency	**Conductive hearing loss**	**Mixed hearing loss**	**Sensorineural hearing loss**	**Total**
500 Hz	39	6	3	48
1000 Hz	37	9	3	49
2000 Hz	40	9	3	52
4000 Hz	41	9	4	54
Total	157	33	13	203

For some ears in the clinical group, bone conduction measurements by conductive SISI method could not be computed for all the four frequencies because of audiometric limitation (Maximum H.L. is 110 db). So bone conduction measurement at that frequency for that ear was omitted. Totally, for the clinical group including all the frequencies, 203 bone conduction measurements were made by both conductive SISI method and conventional method.

The range of the bone conduction thresholds by both conductive SISI method and conventional method for clinical group subjects are given in the table 3.

Table – 3 ……next page.

TABLE – 3

Frequency	Clinical group in total		Cond. hearing loss		Mixed hearing loss		S.N. hearing loss	
	Cond. SISI method	Convent. method	Cond. SISI method	Convent. method	Cond. SISI method	Convent. method	Cond. SISI method	Convent. method
500 Hz	0 to 45	0 to 50	0 to 25	0 to 25	15 to 45	20 to 50	20 to 45	25 to 50
1000 Hz	-5 to 50	0 to 50	-5 to 40	0 to 25	20 to 45	20 to 50	45 to 50	45
2000 Hz	-10 to 50	-5 to 55	-10 to 30	-5 to 25	15 to 50	15 to 55	15 to 45	25 to 50
4000 Hz	-5 to 55	5 to 60	-5 to 30	5 to 30	10 to 55	5 to 60	25 to 50	35 to 45

In general, bone conduction thresholds ranged from -10 db HL to 55 db HL for conductive SISI method and -5 db HL to 60 db HL for conventional method.

Table 4 gives the mean bone conduction thresholds, standard deviation (SD), Standard error of the difference between two means (SE_D) and critical ratio (C.R.) for both conductive SISI test and conventional method for the total clinical group.

TABLE – 4

Fre-quency	Mean B.C. TH's (in db H.L.)		Standard deviation (S.D.)		SE_D	C.R.
	Cond. SISI Method	Convent. Method	Cond. SISI Method	Convent. Method		
500 Hz	16.80	19.065	11.10	11.70	2.327	0.9733
1000 Hz	18.78	17.55	13.675	12.70	2.66	0.1624
2000 Hz	16.345	19.62	12.60	11.88	2.401	1.3640
4000 Hz	19.535	19.40	11.635	11.47	2.223	0.607

Results show that there is no significant different between the means by conductive SISI test and conventional bone conduction test at both 0.05 and 0.01 probability level. So the null hypothesis for all the frequencies for the total clinical group has been retained. The variability within which the individuals perform was similar in both the groups.

CONDUCTIVE HEARING LOSS GROUP:

Similar measurements as shown in Table 4, are given in Table 5, for conductive hearing loss group.

TABLE – 5

Fre-quency	Mean B.C. TH's (in db H.L.)		Standard deviation (S.D.)		SE_D	C.R.
	Cond. SISI Method	Convent. Method	Cond. SISI Method	Convent. Method		
500 Hz	13.25	15.15	6.85	7.56	1.633	1.1633
1000 Hz	13.11	11.625	7.40	6.45	1.613	0.9206
2000 Hz	21.75	15.125	8.255	7.10	1.721	1.9610
4000 Hz	16.10	15.45	8.15	6.75	1.65	0.339

For the frequencies 500 Hz, 1000 Hz, and 4000 Hz the null hypothesis has been retained. i.e., there is no significant difference between the two means at both 0.05 and 0.01 level. But at 2000 Hz for this group of subjects there is a significant difference between the mean bone conduction thresholds by conductive SISI test and by conventional method at 0.05 level. At 2 KHz the mean bone conduction threshold by conductive SISI method was less than the conventional method. The differences obtained at this frequency between the two methods is not significant at 0.01 probability level. As for general purpose, 0.05 level is taken into consideration, because it covers 95% of the population the difference at this frequency between the tow methods can be considerate as significant.

The difference between conventional bone conduction threshold and conductive SISI thresholds at 2 KHz may be attributed to Carhart notch. Carhart notch might be responsible for the increased mean value in conventional method. This shows that conductive SISI method is not influenced by mechanical distortion unlike conventional bone conduction method.

Conductive hearing loss behaves like a normal ear in detecting 1 db increments when the conductive barrier is overcome, is again supported by this study.

MIXED HEARING LOSS AND SENSORINEURAL HEARING LOSS GROUP:

Table 6 and table 7 give the mean bone conduction thresholds, standard deviation (SD), Standard error of the difference between two means (SE_D), and critical ratio (CR) for both the methods for mixed hearing loss and sensorineural hearing loss groups respectively.

TABLE – 6

For Mixed Hearing Loss Group

Fre-quency	**Mean B.C. TH's (in db H.L.)**		**Standard deviation (S.D.)**		**SE_D**	**C.R.**
	Cond. SISI Test.	**Convent. Method**	**Cond. SISI Method**	**Convent. Method**		
500 Hz	26.65	33.35	8.95	9.85	5.458	1.282
1000 Hz	32.20	32.80	9.15	8.85	4.23	0.141
2000 Hz	31.15	33.33	12.20	12.695	5.851	0.376
4000 Hz	26.65	29.00	14.16	15.65	7.012	0.335

TABLE – 7

For Sensorineural Hearing Loss Group

Fre-quency	Mean B.C. TH's (in db H.L.)		Standard deviation (S.D.)		SE_D	C.R.
	Cond. SISI Test	Convent. Method	Cond. SISI Test	Convent. Method		
500 Hz	35.00	41.70	10.80	11.80	9.153	0.732
1000 Hz	48.35	45.00	2.33	0.00	1.344	2.492
2000 Hz	33.35	38.35	13.10	10.275	9.533	0.524
4000 Hz	38.75	38.75	9.60	4.40	5.22	0.00

In these two clinical groups at all frequencies the null hypothesis has been retained implying that there is no significant difference between the two means.

To find the Test Retest reliability, on ten normal hearing ears the test to find the hearing level at which 100% SISI occurs was repeated. Sufficient time was given to avoid the practice effect. The variation was within ± 5 db for all the ears except one ear at 2 KHz. Reliability was statistically computed by using the "Rulon Method" as given by Guildford*.

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* Guilford, J.P. (1965) "Fundamental Statistics in Psychology and Education". McGraw-Hill Book Company, New York.

Reliability coefficient values are given in Table 8 for different frequencies.

TABLE – 8

Frequency	Mean hearing level (100% SISI) in db HL		Reliability Coefficient
	Test	Retest	
500 Hz	64.5	65.0	0.971
1000 Hz	67.0	66.5	0.972
2000 Hz	64.5	63.5	0.938
4000 Hz	65.0	64.0	0.97

The Test Retest reliability was found to be high for all the frequencies.

In general there is no significant difference between the bone conduction thresholds by conductive SISI method and conventional method except at 2 KHz for conductive hearing loss group. For the conductive hearing loss group at 2 KHz conductive SISI test yields better (Lower thresholds than the conventional method.

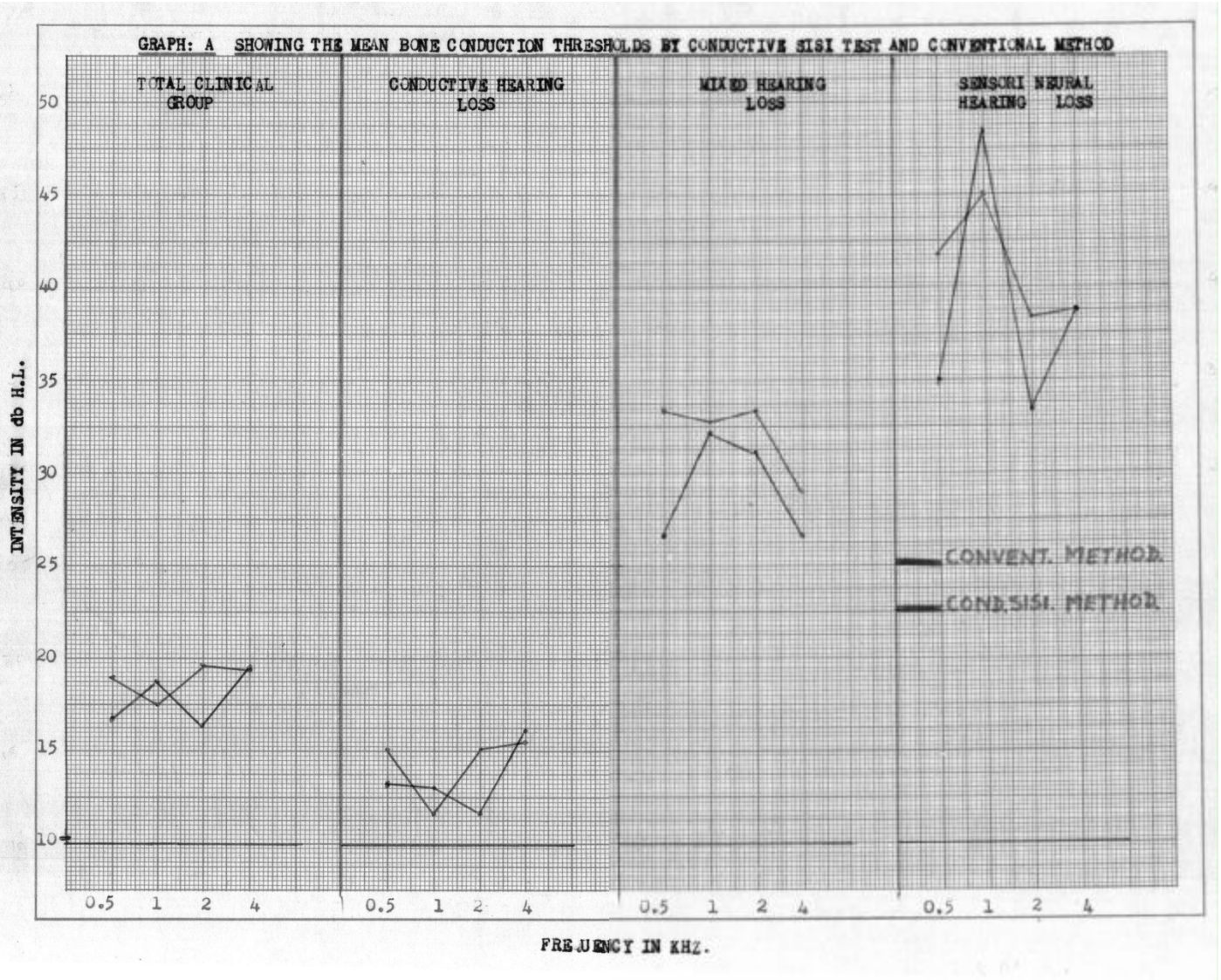
The graph ‘A’ indicates the mean bone conduction thresholds for the total clinical group, conductive hearing loss group, mixed hearing loss group and for the sensorineural hearing los group by both the methods.

In total clinical group, in conductive hearing loss and in sensorineural hearing loss groups at 1 KHz the mean conventional bone conduction thresholds are lower than the conductive SISI thresholds. But in mixed hearing loss at 1 KHz the mean bone conduction thresholds by conductive SISI method is less than conventional bone conduction thresholds. But the difference is only 0.6 db. Only in mixed hearing loss group at all the four frequencies the mean conductive SISI bone conduction thresholds dropped below the mean conventional bone conduction thresholds.

Dirks and Malmquist (1969) state that cases with mixed hearing loss may be misdiagnosed because the effects of middle ear impairment, depress bone conduction thresholds.

Probably better conductive SISI bone conduction thresholds in mixed hearing loss cases at all frequencies can be explained on the basis of Dirks and Malmquist’s observation.

GRAPH: A SHOWING THE MEAN BONE CONDUCTION THRESHOLDS BY CONDUCTIVE SISI TEST AND CONVENTIONAL METHOD



CHAPTER – V

SUMMARY AND CONCLUSION

To find at what level normals score 100% SISI, ten normal hearing subjects were administered SISI test. Twenty ears were tested. The tests were carried out at four frequencies viz: 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz. To find the reliability of the procedure the same test was repeated on the same subjects after sufficient interval to avoid the practice effect.

In the second part, bone conduction thresholds by both conductive SISI test and conventional method were obtained for 43 conductive hearing loss ears, 9 mixed hearing loss ears and 4 sensorineural hearing loss ears and were compared.

CONCLUSION OF THE STUDY:

1. 100% SISI is observed at 65.12 db H.L. (mean value) in normal hearing subjects. Hearing level to obtain 100% SISI in normal ranges from 50 db H.L. to 80 db H.L.

2. There is significant difference in bone conduction thresholds by these two methods at 2000 Hz for

conductive hearing loss group. The difference in bone conduction thresholds by these two methods at 2000 Hz may be attributed to Carhart notch.

3. Conductive hearing loss ears behave like normal ears in detecting 1 db increments of SISI test when the conductive barrier is overcome.

4. There is no significant difference in bone conduction thresholds by both conductive SISI and conventional method at all the frequencies for mixed hearing loss and sensorineural hearing loss group, and except at 2000 Hz for conductive hearing loss group.

5. Test Retest shows high reliability.

6. In mixed hearing loss cases the effects of middle ear impairments may be responsible for depressed bone conduction thresholds when measured by conventional method.

IMPLICATIONS OF THE STUDY:

True bone conduction thresholds can be measured in conductive hearing loss cases by using conductive SISI test, whereas middle ear impairment influence the conventional bone conduction test. Conductive SISI test may

give better picture about the cochlear reserve in mixed hearing loss case which will help in selection of cases for surgery. Conductive SISI test has value when bone conduction measurement by conventional method is questionable and when direct measurement of bone conduction is not possible.

LIMITATIONS OF THE STUDY:

1. The study is limited to four frequencies.
2. Different middle ear pathological conditions have not been studied separately.

RECOMMENDATIONS FOR FURTHER RESEARCH:

1. Different clinical groups and different middle ear pathological conditions (eg. Otosclerosis, Otitis media etc.) can be studied extensively.
2. Conductive SISI test can be tried at 250 Hz to study the bone conduction response in severe hearing loss cases. This may help in differentiating Pseudo bone conduction thresholds and real bone conduction thresholds.
3. The usefulness of conductive SISI test at high frequencies (6000 Hz and 8000 Hz) can be studied

to get the bone conduction thresholds in conductive high tone loss cases.

4. The SISI test can be made objective by associating with P.G.S.R.

5. The level at which central auditory disorder cases show 100% SISI may be determined and the obtained level may be compared with normals.

BIBLIOGRAPHY

Berry, R.C. and Tokay, F.H. (1971). The effect of several occluding devices on bone conduction thresholds and S.P.L.'s in the occluded meatus. J. Aud. Res. 11, 69-72.

Boothroyd, A., and Cawkweel, S. (1970). Vibrotactile thresholds in pure tone audiometry. Acta Oto Laryngol. 69; 381-387.

Byers, V.W. (1974) Conductive SISI test. Ann. Otol. 83; 125-127.

Carhart, R. (1962). Effects of stapes fixation on bone conduction responses. In "Hearing Measurement" (Ventry, I.M., Chaiklin, J.B., and Dixon, R.F. ed). article 12. Appleton – Century – crofts. Meredith Corporation, New York, 1971.

Davis, H., (1970) Audiometry: Pure tone and simple speech tests. In "Hearing and Deafness" (Hallowel Davis and Richard Silverman ed.). 3rd Ed. Chap. 7, Holt, Rinehart and Winston, New York.

Davis, H., and Golstein, R.(1970) Audiometry: Other auditory tests, In "Hearing and Deafness". (Hallowel Davis and Richard Silverman ed.) 3rd ed. Chap. 8, Holt, Rinehart and Winston, New York.

Dayal, V.S., Wortzman, G., Hands, C.F. (1972), Low frequency bone conduction response in deaf children. Ann. Otol. 81, 429-432.

Dirks, D.D. (1964). Factors related to bone conduction reliability. Arch. Otolaryngol. 79; 551-558.

Dirks, D.D. (1964). Bone conduction measurements. Arch. Otolaryngol. 79; 594.

Dirks, D.D. and Malmquist, C (1964). Changes in bone conduction threshold produced by masking in the non-test ear, J. Speech Hearing Res. 7; 271-278.

Dirks, D., Malmquist, C., and Bower, D. (1968). Toward the specification of normal bone conduction thresholds. J. Acous. Soc. Amer. 43; 1237-1242.

Dirks, D.D. and Malmquist, C.M. (1969). Comparison of frontal and mastoid bone conduction threshold in various conductive lesions. J. Speech and Hearing Res. 12; 725-746.

Dirks, D.D. (1972). Clinical measurement of bone conduction. In "Handbook of clinical Audiology". (Jack Katz ed.) Chap. 6 The Williams and Wilkins Co. Baltimore.

Dirks, D. (1973), Bone conduction measurements. In Modern developments in Audiology" (Jerger, J. ed.). Second ed. Chapter I, Academic Press, New York.

Feldman, A.S. (1961). Problem in the measurement of bone conduction. J. Speech and Hearing Disorder. 26; 39-44.

Feldman, A.S. (1963). Maximum air conduction hearing loss, J. Speech and Hearing Res. 6; 157-163.

Feldmann, Harald (1970). "A History of Audiology" Translations. No. 22. Jan. 1970. Of the Beltone institute for hearing research. Illinois.

Fulton, R.T., and Spradlin, J.E. (1972). Effects of practice on SISI scores with normal hearing subjects. J. Speech and Hearing Res. 15; 217-224.

Garrett, H.E. (1971) Statistics in Psychology and education, Vakils, Feffer and Simons Private Ltd., Bombay.

Goldstein, D.P., Hayes, C.S., & Peterson, J.L. (1962). A comparison of bone conduction thresholds by conventional and Rainville method. J. Speech and Hearing Res. 5; 244-255.

Goldstein, D.P., and Hayes C,. S., (1965). The occlusion effect in bone-conduction hearing . In "Hearing measurement". (Ventry, I.M., Chaiklin, JB., and Dixon, R.F. ed.). article 15, Appleton – Century – Crofts, Meredith corporation, New York 1971.

Hanley, C.N., and Utting, J.F. (1965). An Examination of the normal hearers response to the SISI. J. Speech and Hearing Disorder. 30; 58-65.

Harbert, F., and Young, I.M. (1969) The low frequency air bone gap in sensorineural deafness. Ann. Otol. 78, 107-111.

Harbert, ., Young, Im.M., and Weiss, B.G. (1969). Clinical application of intensity difference Limen. Acta Oto Laryngol, 67; 435-443.

Hickling, S. (1968). Experimental studies realating to the SISI test. J. of aud. Res., 8; 477-481.

Hirschorn, M. (1967). Acoustical environment for industrial audiometric programs. In "Hearing Measurements". (Ventry, I.M., Chaiklin, J.B. and Dixon, R.F. ed.) article. 8. Appleton-Century-Crofts, Meredith corporation, New York, 1971.

Hood. J.D. (1960). The principles and practice of bone conduction Audiometry. In Hearing Measurement". (Ventry, I.M., Chaiklin, J.B., and Dixon, R.F. ed.). article 37. Appleton-Century-Crofts. Meredith Corporation, New York, 1971.

Hughes, R.L. (1968). A typical responses to the SISI Ann. Otol. 77; 332-337.

Huizing, E.H. (1970). Lateralization of bone conduction into the better ear in conductive deafness. Acta oto laryngol. 69; 395-401.

Hurley, R.M., and Berger, K.W. (1970). The relationship between vibrator placement an bone conduction measurements with monaurally deaf subjects. J. Aud. Res. 10; 147-150.

Isele, R.W., Berger, K.W., Lippy, W.H., and Rotolo, A.L., (1968). A comparison of bone conduction threshold as measured from several clinical locations. J. Aud. Res. 8; 415-419.

Jerger. J (1968). Review of diagnostic audiometry, Ann. Otol. 77; 1042-1053.

Jerger, J. (1973) Diagnostic audiometry. In Modern developments in Audiology" (Jerger, J. ed.) second ed. Chap. 3. Academic Press. New York.

Katinsky, S., Lovrinic, J. and Buchheit, W. (1972). Cochlear findings in VIII nerve tumorus. Audiology. 11; 213-217.

Liebman, J. (1968). Skull vibration influences upon the occlusion effect in bone conduction hearing. J. Aud. Res. 8; 283-289.

Martin, F.N., and Schlieffer, A (1969). The occlusion effect with the bone conduction vibrator placed on the mastoid versus the forehead. J. Aud. Res. 9; 207-210.

Martin, F.N., and Salas, C.R. (1970). The SISI test and subjective loudness. J. Aud. Res. 10; 368-371.

Martin F.H. (1972). The short increment sensitivity index In "Handbook of Clinical Audiology". (Jack Katz ed.) The Williams and Wilkins Co. Baltimore.

Mary John (1973). Standardization and Clinical Applicability of sensor-neural-acuity level test. Dissertation submitted to University of Mysore 1973 for Master's Degree.

Matkin, N.D., and Olsen, W.O. (1971) Differential Audiology In "Audiological assessment". (Rose, D.E. ed.). Chap.10. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

McCrimmen (1957). "Writing with a purpose" The Riverside Press. Cambridge. Second edition.

Newby, H.A. (1972) "Audiology", Appleton-century-crofts. Meredith Corporation, New York.

Nober. E.H. (1964). Psudoauditory bone conduction thresholds. J. Speech and Hearing Disord. 29; 469-476.

Olsen, W.O. (1967). Artificial mastoid calibration of bone vibrators. Archives Otolaryngel. 85; 314.

O' Neill, J.J., and Oyer, H.J. (1966) "Applied Audiometry" Dodd, Mead and Company, Inc. New York.

Owens, E. (1965), The SISI test and VIII nerve versus Cochlear involvement. J. Speech and Hearing-Disord. 30; 252-262.

Paparella. M.M., Oda. M., Hiraide, F., and Erady, D (1972) Pathology of sensorineural hearing loss in otitis media. Ann. Otol. 81; 632-647.

Price, L.L. (1971). Pure tone audiometry. In "Audiological assessment (Rose, D.E.ed) Chap. 6, Prentice Hall, Inc., Englewood cliffs, New Jersey.

Pushpa, G., (1974) The effect of test tone levels and contralateral masking noise level on the SISI scores for normal and sensorineural hearing loss cases. Dissertation submitted to University of Mysore 1974 for the Master degree.

Rahko, T. (1971), SISI test and adaptation. Acta oto Laryngol. 72; 344-351.

Reger, S.N. (1968). Pure tone audiometry. In "Audiometry: Principles and Practices" (Aram Glorig ed). Chap. 6 The Williams and Wilkins Company, Baltimore.

Rintelman, W.F., Orchik, D.J., Stephens, M.M. (1972). A Comparison of puretone and warble tone thresholds. Research investigation from Department of Audiology and Speech Sciences. Michigan State University.

Roach, R.E. and Carhart, R (1956). A Clinical method for calibrating the bone conduction audiometer. In "Hearing Measurement. (Ventry, I.M., Chaiklin, J.B., and Dixon, R.F. ed.). Article 3, Appleton-century-crofts-Meredith Corporation, New York 1971.

Robinson, M., Kasden, S.D. (1970). Bone conduction speech audiometry. Ann. Otol. 79; 818-824.

Rubinstein, M., Lipman, B., Yundef, H., and Luz.H., (1970). SISI findings in Normal subjects. Acta Oto laryngol. 69; 112-116.

Sabatino, D.A. and Stromsta, C.P. (1969), Bone conduction thresholds from three locations on the skull. J. Aud. Res. 9; 194-198.

Sala, O. (1973). Clinical significance and diagnostic value of auditory bone threshold. Acta Oto Laryngol 75; 152-155.

Sanders, J.W., and Rintelman, W.F. (1964). Masking in Audiometry. In "Hearing Measurement" (Ventry, I.M. Chaiklin, J.B., and Dixon R.F. ed.) article 32. Appleton-century-crofts, Meredith Corporation, New York, 1971.

Sanders, J.W., and Olsen, W.O. (1964). An evaluation of a new article mastoid as an instrument for the calibration of audiometer bone conduction system. J. Speech and Hearing Disorder. 29; 247-263.

Sanders, J.W. and Simpson, M.E. (1966). The effect of increment size on SISI scores. J. Speech and Hearing Res. 9; 297-304.

Schuchman, G., and Burgi, E.J. (1971) . The effect of jaw position on hearing by bone conduction. J. Aud. Res. 11; 142-131.

Simonton. K.M. (1968). Audiometry and diagnoses. In "Audiometry: Principles and Practices". (Aram Glorig ed). Chap.9. The Williams and Wilkins Company, Baltimore.

Studebaker, G.A. (1962). On masking in bone conduction testing. J. Speech and hearing Res. 5; 215-227.

Studebaker, G.A. (1962). Placement of vibrator in bone conduction testing. J. Speech and Hearing Res. 5; 321-331.

Studebaker, G.A. (1967) The standardization of bone conduction thresholds. In "Hearing Measurement" (Ventry, I.M. Chiklin, J.B., and Dixon, R.F. ed.) Article. 4, Appleton-century-crofts, Meredith Corporation, New York, 1971.

Studebaker, G.A. (1967). Intertest variability and the airbone gap. In "Hearing Measurement". (Ventry I.M., Chaiklin, J.B. and Dixon R.F.) article 17, Appleton-century-crofts. Meredith Corporation New York 1971.

Thompson, G (1963). A modified SISI technique for selected cases with acoustic neuroma, J. Speech and Hearing Disorder. 28; 299-302.

Tondorf. J. (1968). A new concept of bone conduction. Arch. Otolaryngol. 87; 595.

Veniar, F.A. (1965) Individual masking level in puretone audiometry. In "Hearing Measurements" (Ventry, I.M. Chaiklin, J.B., and Dixon, R.F. ed.) article 38. Appleton-century-crofts-Meredith Corporation, New York, 1971.

Ventry, I. M. Chaiklin, J.B., and Dixon, R.F. (1971) Measurement of puretone thresholds. In "Hearing Measurement". Part II, 93-95. Appleton Century – crofts, Meredith Corporation, New York 1971.

Wearherton, M.A., and Geetzinger, C.P. (1971). A report on bone conduction thresholds at the mastoid and forehead in normals. Audiology, 10; 23-29.

Wilber, L.A. and Goodhill, V (1967). Real ear versus artificial mastoid methods of calibration of bone conduction vibrators. J. Speech and Hearing Res. 10; 405-416.

Wilber. L.A. (1972). Calibration: Puretone, Speech and Noise signals. In "Handbook of Clinical Audiology" (Jack Katz ed.) Chapter 2, The Williams and Wilkins Co., Baltimore.

Yantis, P.A., and Decker, R.L. (1964). On the short increment sensitivity index. J. Speech and Hearing Disorder. 29; 231-246.

Young, I.M., and Harbert, F (1967). Significance of the SISI test. J. Aud. Res. 7; 303-311.

Young, I.M. and Wenner, C.H. (1968). Effects of masking noise on the SISI test. J. Aud. Res. 8, 331-337.

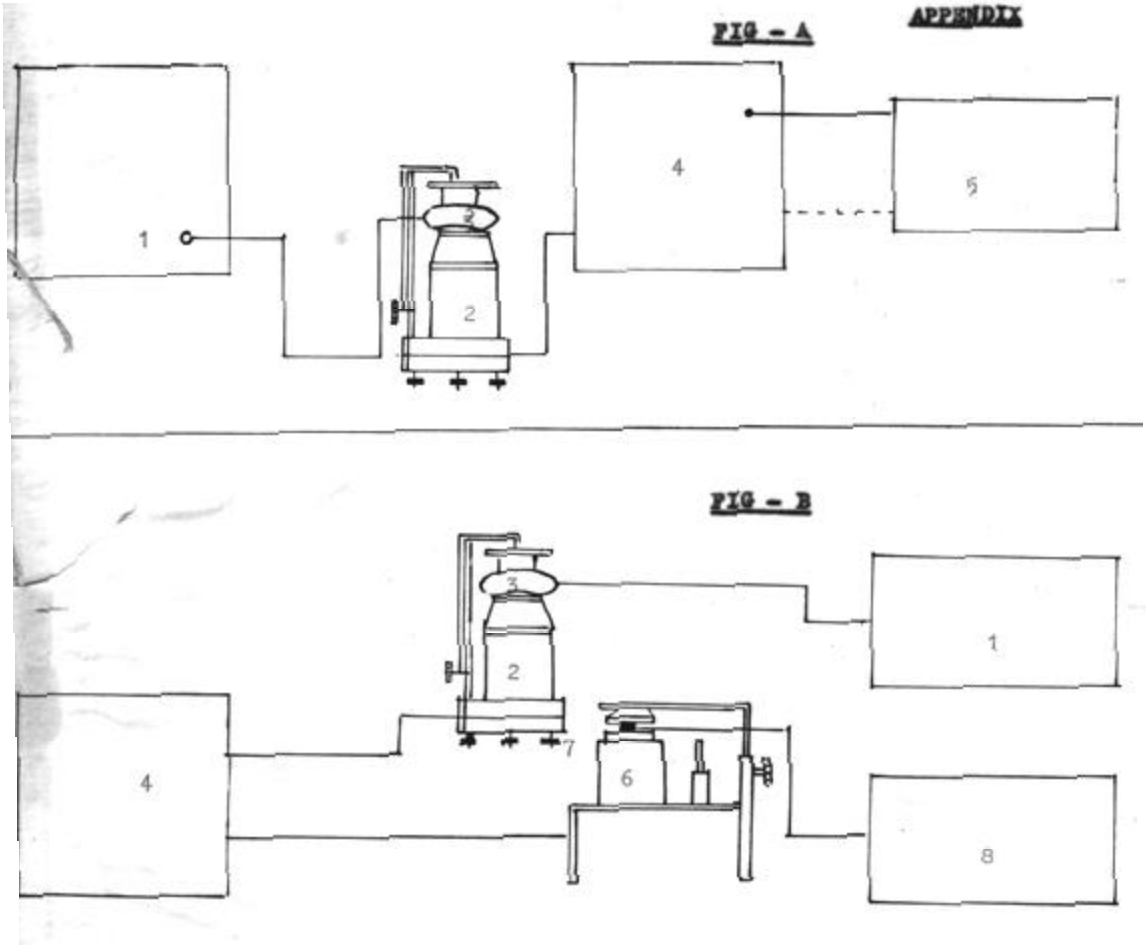


Fig. A. – Block Diagram showing the Experimental set up for SISI calibration.

Fig. B. – Block Diagram showing the Experimental set up for Puretone (Air Conduction and Bone Conduction) Calibration.

1. Audiometer : Beltone 15 CX
2. Artificial Ear: B & K Type 4152
3. Earphone : TDH 39
4. Audiofrequency Analyzer: B & K Type 2107.
5. Level Recorder : B & K Type 2305
6. Aftificial Mastoid: B & K Type 4930
7. Bone Vibrator
8. Audiometer: Madsen TBN 60