# CONDUCTIVE SISI AT LOWER FREQUENCIES

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# CERTIFICATE

This is to certify that the Independent Project entitled: "CONDUCTIVE SISI AT LOWER FREQUENCIES" is the bonafide work, done in part fulfilment for First Year M.sc.,(Speech and Hearing) of the student with Register Number 8608.

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## CERTIFICATE

This is to certify that the Independent Project entitled "CONDUCTIVE SISI AT LOWER FREQUENCIES" has been prepared under my supervision and guidance.

Dr.M.N.Vyasamurthy
Guide.

# DECLARATION

This Independent Project Entitled "CONDUCTIVE SISI AT LOWER FREQUENCIES" is the result of my own study undertaken under the guidance of Dr.M.N.Vyasamurthy, Department of 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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# INTRODUCTION

# INTRODUCTION

Pure tone tests are the basic tests to find hearing sensitivity and are also the basic clinical tools for initiating differential diagnosis. These tests also suggest the site of lesion.

Daring the early pact of 19th century. Bone conduction valves were used diagaostically, to differentiate conductive hearing loss and senaorinearal loss. Bone-conduction values provide the sensitivity of the auditory mechanism as a functional unit.

In the past three decades the measurement of bone-conduction threshold has gained clinical importance because of the development of new surgical procedures. The magnitude of the conductive component is indicated by the discrepancy between air conduction threshold and bone conduction threshold.

Inspite of the importance and extensive use of bone—conduction measurements the clinical assessment has been plagged by numerous inherent problems. Carhart and Hayes (1950); Fieldman (1961) have pointed out the reliability of measuring bone conduction thresholds, Which has been widely mistrusted. Because of the errors arising from several sources, the reliability and validity of bone conduction results are limited. The potential sources of error can be instrumental.

subject selection error, experimenter error or physiological technique. At the same time basic principles of bone conduction audiometry are not clearly understood, and so the tests are often used inefficiently and inaccurately.

Among the number of variables which affect the bone conduction threshold, important variables are:

1. Physical characteristics of bone conduction vibrators
2. The force applied to the bone conduction vibrator on the skull.
3. Placement of bone conduction vibrators.
4. Pallesthesia.
5. 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.

Further the calibration of bone conduction vibrator is very important and a major variable. Till today there is no one standard method of calibration of bone conduction vibrators. The problem of calibration has been solved to some extent after artificial mastoids came into the picture. The calibration of the bone conduction vibrator is more difficult than that of the earphone and the reference zero values are less clearly defined (Davis and Goldstein, 1970). The basic problem in bone conduction vibrator's calibration is the lack of reliable instrument for measuring the output.

Lateralization further creates problems for the testing of bone conduction thresholds. Interaural attenuation for bone conduction is negligible irrespective of the placement of the vibrator on the skull. so, unless the non-test ear is masked by an adequate air conduction masker, getting true thresholds for the test ear is not possible for the bone conduction skimuli. But there are divergent opinions about when the mask and amount of noise to be given etc. Even central Masking affects bone conduction thresholds. In bilateral conductive loss cases (Naunton's Dilema) Masking is not possible. Some times patients have hearing loss so severe that the contralateral ear cannot be masked. Or even if masking is tried in some patients it is ineffective (Leden et al 1959 and Hood, I960). The pattern of hearing loss changes the quality and effectiveness of whitenoise (Naunton, 1952; Zwislocki, 1951). Air-bone gap in the masked ear increases the minimum masking by an amount equal to the air-bone gap. Air bone gap in the teat ear reduces the maximum masking by an amount equal to the air-bone gap.

Bone-conduction thresholds should be normal in pure conductive loss cases theoretically. The bone conduction sensitivity is not independent of the state of the middle ear has been indicated. The measurement of bone conduction cannot be considered as an exact indication of the cochlear reserve in cases of stapes fixation. One sees Carhart notch in otosclerosis cases. External ear and/or middle ear impairments such as mastoidectomy (Bekesy, 1939; and Tandorf, 1966). Otitis Media (Hulka, 1941; Naunton and Fernandaz, 1961; Carhart, 1962; Huizing, 1964; Dirks and malmquist, 1969) and malleal fixation (Goodhill, 1966) can after the bone conduction thresholds. Producing a positive or negative change of air pressure in the external auditory meatus causes a change is sensitivity for bone conduction as well as for air conduction. (Donald Dirks, 1973). A bone conduction curve is better than normal at low frequencies and poorer than normals at high frequencies is common in middle ear disease (Lierle and Reger, 1946). Usually bone conduction thresholds are not normal in cases of otosclerosis.

An accurate measurement of bone conduction sensitivity is very important because precise measurement of bone conduction thresholds gives essential diagnostic clues and also the treatment depends to greater extent on bone conduction measurements.

Some other tests were developed in order to overcame some of the above mentioned problems to measure bone conduction sensitivity.

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

These tests too have few demerits. Vincent W Byers (1974) gave one test to measure bone conduction sensitivity and is called as "conductive SISI test". This test is based on short increment sensitivity Index (SISI) test. Here the hearing level at which 100% SISI score results is are determined. Then the bone conduction threshold can be determined by using the formula: BCTH dB = 60dB + ACTH dB - H.L dB (100% SISI) when direct bone conduction measurements are not possible or when a bone conduction threshold is questionable then conductive SISI test can be used to determine Bone conduction thresholds.

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

An attempts was made by Narendran in (1975) to know the validity of this technique at four test frequencies viz. 500Hz, l000Hz, 2000Hz and 4000Hz.

The present study was planned to verify the usefulness of "conductive SISI" test as a clinical tool in determining the bone conduction thresholds at low frequencies viz. 250Hz and 500Hz.

## Purpose of the study:

The purpose of the study was to test the following null hypothesis.

1. There is no significant difference between bone conduction threshold obtained by conductive SISI test at low frequencies

(250Hz, 500Hz) and conventional bone conduction threshold obtained in normals, conductive hearing loss and sensory neural hearing loss patients.

Brief plan of the study:

Conventional bone conduction tests and conductive SISI test were administered to conductive hearing loss patients, sensorineural hearing loss patients and on 15 normal subjects. All the measurements were done in a sound treated room using GSI-16 Audiometer. The conventional bone-conduction thresholds and bone conduction thresholds obtained by conductive SISI test were compared. Subjects with normal hearing served as a criterian group to find the hearing level at which 100% SISI scores in obtained. The test was administered at two test frequencies viz. 250Hz and 500Hz.

# REVIEW OF LITERATURE

# REVIEW OF LITERATURE

One known fact that the principal abjective of pure tone audiometry is to determine the sensitivity of the human auditory system. The main objectives of the pure tone audiometry are:

1) to find out the earliest sound a person can hear.
2) how a person hears and where he hears. A more sophisticated view holds that pure tone audiometry is a measure of the sensorineural apparatus and the adequacy of the mechanical system of the ear. Thus testing bone conduction acuity provide information for the 1st area (sensorineural apparatus) while air-conduction testing provide us with some information about both areas.

Bone conduction phenomenon is more complex and complicated than air conduction. The clinical testing of bone conduction has long been essential and important in the measurement of cochlear reserve. Carhart (1950) and Feldman (1961) pointed out, the reliability of measuring bone conduction thresholds has been widely mistrusted.

In clinical audiometry bone-conduction measurements are frequently used. Bekesy (1932) was the first man to demonstrate that mode of excitation of the cochlear receptors was same for both air conduction and bone conduction signals.

Comparison of air conduction and bone conduction threshold is still the most definitive method for determining the degree and type of hearing loss (Ventry et al, 1971). The measurement of bone conduction thresholds must be reliable and valid for the differential diagnosis. Carhart and Hays (1950) and Feldman (1961) questioned the reliability of the bone conduction measuremennts.

Several variables have been singled out in the literature as having special influence on the reliability of bone conduction measurements, such as type of vibrator employed force exerted by the vibrator, the presence or absence of a masking stimulus in the non-test ear, the location of the vibrator on the skull.

Air pressure variation in external auditory canal loading of tyapanic membrane, alteration or removal of structures of the middle ear, occlusion effect, size of the bone conduction vibrator, individual differences in the mass of the head and ambient noise level.

Donald Dirks (1964) found that consistently greater electrical output from the automatic audiometer was needed to reach threshold with the grenade vibrator than with the hearing aid type vibrator, Sanders and Olsen (1964) and Wilber and Goodhill (1967) have reported undesired harmonic distortion at low frequencies for a modern hearing aid type vibrator. The physical characteristics of bone conduction vibrators are different from air conduction receivers and are more problematic. They need more power than the air conduction vibrators in order to reach the threshold in normal ear.

The force applied to the bone conduction vibrator on the skull is another variable ia 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, 1966).

Less energy is required to reach threshold by bone conduction as vibrator force is increased. Application force of the vibrator significantly affects the threshold and acts differentially across both frequency and vibrators (Konig,1957). Konig (1957) suggested that bone conduction receiver application force of 1000 grams is desirable in clinical audiometry. In the proposed, international standards for bone conduction thresholds the suggested application force will be approximately 500 grams for a bone vibrator with a plane circular face area of 1.75 $cm^2$.

Bone conduction vibrator has to be placed properly for maximum sensitivity of the patient. Bone conduction vibrator can be placed at various locations. The frontal bone and mastoid process have received the most attention aa sites of placement of the vibrator though teeth and vertex of the skull can also be used as place of bone vibrator (Barany, 1938; studebalker, 1962). Vibrator cannot be placed anywhere on the cranium because of the placement problem and discomfort to the patients. The relative threshold, also varies depending upon the position of placement on cranium.

Bekesy (1982), Link and zwislocki (1951) and Hood (1957) advocated the use of positions along the medium sagital bene such as the forehead or vertex. 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). Frontal bone tissue is homogenous. Studebaker (1952) and Dirks (1964) did not show test-retest-differences. At forehead the bone density and skin thickness vary less, hair and cartilage do not interfere and airconduction leakage through the vibrator is less of a problem,there is a reduction of localization by virtue of suggestion.

while some clinicians advocate forehead placement of the bone conduction vibrator, mastoid placement has one outstanding virtues hearing is more sensitive with this placement, as opposed to fore-head placement,by a factor of 5 to 15dB, depending upon frequency. At 250Hz, the mean data show that mastoid placament results in 15dB better thresholds than forehead placement while at 4000Hz, this difference is closer to 5dB (Dirks, 1978).

The participation of middle ear is less at frontal placement of boneconduction vibrator. Link and zwislocki (1951) using patients with middle ear pathology found the pathology exers less influence upon boneconduction from forehead than it does in mastoid placament. Lipply et al(1966) indicate, improved boneconduction thresholds; particularly at 500Hz and 100OHZ are obtained when the bone oscillator was placed on the central incissors rather than the mastoid area.

Frontal placement of vibrator has few demerits. Link and Zwislocki (1951) and studebaker (1962) show that the thresholds at forehead are higher at all frequencies thaa those obtained at mastoid. Feldman (1961) shows in a study that the thresholds at frontal placement is 10dB higher than the mastoid thresholds. 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.

Generally bone-conduction threshold is expected to be better when the vibrator application force is increased, but the studies donot agree with this principle. Bekesy (1939) and Konig (1955) found that the change in bone conduction threshold is maximum when the vibrator application force is less than 750 gms and a very small change was found when the static force was 1800 and 1500 gms. Depending on these findings Korg suggested that the coupling force should be approximately l000gms to have a minimum variability of bone-conduction threshold.

Harris et al (1953) investigated the effects of increased application force from 100 to 500 gms, at the test frequencies of 250, 1000 aad 8000Hz. The greatest change in the threshold was found at 250 Hz. according to them, the application force should be standardized somewhere between 200 gms. to 400 gms. The results of the two aforesaid studies do not agree with each other. Dadson (1954) observed change in mechanical impedance by varying the force of application. According to the international standards for bone conduction thresholds, the bone-conduction vibrator application force should be approximately 500 gms for a bone vibrator with a plain circular face of 1.75cm$^2$ commertially available head bands exert a static force of approximately 360 gms to 400 gms when the vibrator ig placed on the mastoid process of adult subjects (Dirks, 1965; Staudebaker, 1962).

M.N.Vyasamurthy et al. (1977) studied the change to bone conduction output for various force values from 100 gms to lOOOgms in 100 gms steps. The result indicates a little change in bone conduction. Output at 250 Hz for the static forces were ranging from 100 gms to 1000 gms and the change was more at the frequencies 3 KHz and 4 KHz for the lower static forces. However the change in bone conduction output was very little for a static force of 400 gms to 1000 gms for all the test frequencies.

There are few factors which cannot be controlled by the examiner i.e. the mass of the head, the thickness, the density and elasticity of the bones. Of the many researchers including, Bekesy (1932) and Barany (1938) have pointed out that placement of vibrator on the mastoid has disadvantages, because:

1) Shifts in the position of the vibrator causes larger variation in mastoid placement.
2) Intersubject variation in skin and underlying tissues are greater at the mastoid.
3) Middle ear influence is more at the mastoid.
4) Bone conduction thresholds can be affected because of mastoid aircells.
5) Vibrator may touch the pinna and produce hearing by air conduction.

Although the air conduction pathway ia generally considered to be the principal mode of sound transmission, the movements of a vibrating body may also be transmitted to the inner ear through direct contact with the skull (Dirks, 1974).

Rosenblith (1951) and Kirikae (1955) also agree that shifts of the oscicles in the mastoid is greater than 3 cm in any direction, affects the bone conduction threshold values.

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 intersural attenuation for bone conduction sound ia near zero aad both ears may be stimulated equally by a receiver on either mastoid.

Many researchers used different positions in order to avoid the disadvantages of mastoid placement of bone conduction vibrator, 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.

In bone conduction measurements pallothesia gives false results at low frequencies. When sound vibrations reach a sufficiently high intensities they may be perceived through the sense of touch. Barr (1955) described this as "Artifactual bone conduction". Newby (1964) and Reger (1965) also indicated the presence of vibrotactile sensitivity at low frequencies. Since the bone conduction vibrator is specially designed to transmit mechanical vibrations to the mastoid region, the problem of vibrotactile stimulation becomes more acute in bone conduction audiometry (Boothroyd and Gawklueel, 1970).

Verrillo (1975) suggested that it may be safely assumed that bone conduction thresholds measurements above 1500Hz may have more credibility than those obtained below that frequency.

The calibration of bone conduction receiver has been a problem to the clinical audiologists for years and is another variable. The AMA (American Medical Association) and Hedgecock

(1961) proposed the comparison of air conduction and bone conduction thresholds on normal hearing persons for calibration. Biological calibration may not give good results because intersubjact variability and test retest differences are larger (Wilber and Goodhill 1967). The results of the study by sanders and Olsen (1964) by using Weiirs 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.

lightfood and Hoare (1979) have recently shown significant discrepancies between different vibrators calibrated oa different devices.

Calibration problems can cause difficulty with test reliability. In the past few years a new bone vibrator (the Radioear a-72) has been designed for hearing assessment. This new vibrator appears to have less harmonic distortion at important frequencies for clinical testing and an improved dynamic range at 250Hz. The new vibrator is more bulky and some clinicians complain of difficulty obtaining an adequate comfortable seal on the skull with the new vibrator. This may be due to the new headband assemly designed for the B-72 which yields is excess of 500 gms. of pressure on most heads (Dirks and Kamm, 1975). As of this date, there is no calibration standard accepted by ANSI for the B-72 vibrator. A working approximation can be found by adjusting the ANSI 53.13.1972 standard fox the appropriate placement and artificial mastoid using the data of Dirks aad Kamm (1975); Billings and Winter (1977); and Dirks et al (1979).

Another variable which affects the bone-conduction measurement is lateralization and this is difficult 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. Hood (1957) and Feldman (1961) considered interaural attenuation for bone conductions to be essentially negligible. so, both the cochleas will be stimulated irrespective of the placement of the vibrator. Bekesy (1932), Bareny (1938) and Kirikae (1959) demonstrated that both ears are stimulated to approximately the same extent irrespective of the placement of the vibrator because the vibrator transmits the energy to the whole skull.

So, while doing bone conduction it is necessary to mask the non-test ear for the true thresholds. Disagreement on the appropriate signs and indications for the use of masking in the non-test ear still exists.

Wagel and Lane (1924), Carhart (1950), Zwislocki (1953), Ingham (1957), studebaker (1962) and Treisman (1983) have reported shifts in threshold for bone conduction due to masking in the contralateral ear. As the level of the noise in the non-test ear increases there is a small but gradual shift in the threshold of the teat ear.

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

The masking must be performed carefully at ascending masking levels to attain the true masking 'plateau' at which the test ear is being tested without undue central or cross over masking effects.

An effective masking concept is recommended for clinical use, a more comprehensive coverage of this is provided by Sanders (1978). This approach necessitates construction of an effective masking table for each piece of audiometric equipment used.

Donald Dirks says that the common clinical problems of the nonavailability of sufficient masking in the non-test ear is partially alleviated by the use of narrow band masking. Noise in the non-test ear influence the threshold of the test ear.

A small but gradual shift in the threshold of the test ear with the increase in the noise level in the non-test ear is because of central masking, So, a corrective factor have to be introduced when thresholds are measured, with higher levels of noise in the opposite ear as suggested by Donald Dirks(1967).

While testing conductive impairment occasionally problem of over masking comes in doing bone conduction. Ralph Naunton (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". Because of Naunton's Dilema, optimum masking is not possible in bilateral conductive loss.

Some patients have hearing loss to such an extant that the contralateral ear cannot be masked effectively (Leden et al 1959 and Hood, 1966). Masking is also influenced by the presence of an air bone gap. Air bone gap in the test ear reduces the maximum masking by an amount equal to the air bone gap. Air bone gap in the masked ear increases the minimum masking by an amount equal to the air bone gap.

The phenomenon of occlusion effect further complicates the problem. Kelley and Reger (1937), Martin and schlieffer (l969) and Jerome Liebman (1968) found that occlusion effect is frequency dependent. Occlusion effect is eliminated in middle ear pathologies. Depending upon the pathology, occlusion effect varies. Intersubject variability of occlusion effect is very high, (Feldman, 1961) and Elpern and Naunton, 1963). The occlusion of the ear under test introduces new and not easily controllable variables.

In conductive loss subjects, bone conduction thresholds are expected to be normal but bone conduction loss increases with increasing duration of middle ear disease. Tondorf (1966) suggests that middle ear contribution is not confined to low frequencies as the classical theories suggests. The concepts that stapes fixation eliminates inertial bone conduction is rejected because in clinicsshigh frequency loss is seen.

Patients with otosclerosis who possess normal cochlear and neural functions do not yield completely normal bone conduction audiograms. Carhert (1950) and McConnel (1950) suggests that the typical reduction in sensitivity in stapes fixation cases in 5dB at 500Hz, 10dB at 1000Hz, 15dB at 2000Hz and 5dB at 4000Hz. This depression is the 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 is differential diagnosis. Goodhill (1965) reported a Carhart type notch extending into higher frequencies for a patient with a surgically confirmed malleolar fixation. The amount of bone conduction loss depends, upon the degree of fixation. Donald Dirks (1972) report that the improvement in otosclerosis is due to the mechanical changes in the oscicular system and not due to cochlear modification. Carhart reported that the amount of improvement in the post operative bone – conduction levels correspond closely to the average shifts in the bone conduction level responses due to stapedial fixation. A case in which bone conduction threshold were altered following radical mastoidectomy was demonstrated by Bekesy (1939) and Tondorf (1966). Palva and Ojala (1955) did not find a shift in bone conduction thresholds in otitis media patients. Huising (1960) also reported bone conduction threshold changes in patients with otitis media tubotympanities and chronic inflamatory processes. Improvement in bone conduction thresholds at the lower frequencies when the fluid present in the ears of the bilateral secretory otitis media patients was observed by Naunton and Fernandez(1961). Bluvshtein (1963) reported that 37.5% of his patients with chronic otitis media were found to have some loss of cochlear function. Mastoid and frontal bone conduction thresholds are affected similarly if some alterations are made in the middle ear. (Donald Dirks and Malmquist, 1969).

It has been demonstrated with normal hearing people that bone conduction responses can be altered experimentally by (1) The occlusion of external auditory canal (Pohlman and Kranz 1926, Bekesy, 1932, Kelley and Reger, 1937, Watson and Gales, 1973 et al). (2) Air pressure changes in the external auditory canal (Fowler, 1920; Barany, 1938; Loch, 1942; Kirikae, 1959; Allen and Fernandez, 1960; Huizing, 1960). (3) Loading of the tympanic membrane (Barany, 1938, Rytzner, 1954; Kiraleae, 1959; Allen and Fernandez, 1960; Abu-jaudeh, 1964; Brinkman, Marreas and Lolk, 1965).

Bone conduction thresholds do not represent a pure estimate of cochlear reserve in conductive hearing loss. cases has been demonstrated by the accommulated substantial data. Donald Dirks (1972) reports that this is a short coming.

In clinical audiometry accurate measurement of bone conduction is very important and this condition is not satisfied by the conventional bone conduction audiometry. So, to solve this problem of obtaining more accurate bone conduction values, other alternative methods were developed.

Difference limen technique for establishing sensorineural acuity was described by Jerger in 1953. But this test was not used regularly because of poor standardization.

Rainville in 1955 proposed a modified bone conduction test. but his method proved to be a cumbersome clinical tool. Disadvantages of this method are occlusion effect and problems of instrumentation. Even from auditory adaptation which occurs during the time required to mask the threshold, tone error may occur. Goldstein, Hayes and Peterson (1962) reports that,for the conductive and mixed hearing loss groups the bone conduction thresholds obtained by convention and Rainville techniques were highly similar at 2KHz and 4KHz, but significantly different at 250HZ and 500Hz. But for sensorineural hearing loss group subjects threshold by both the Methods approximated at all levels.

In 1960 Lightfoot modified Rainville technique. Jerger sad Tillman (1960) also modified this technique which is known as sensorineural acuity level (SAL) test. Threshold shifts for pure tones were measured 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 on subjects with normal hearing. The difference between these two are called sensori-neural acuity level.

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

Matkin and Oben (1971) also say that SAL approach cannot be considered as a substitute for bone conduction tests.

Miskolezy Fodor (1956) described brief tone audiometry which is another technique designed to determine the status of sensorineural mechanism. But its use is limited to identify the site of lesion.

SISI test was used to find the bone conduction thresholds in 1974 by Uincent W Byers.

SISI test was Introduced by Jerger, Shedd and Harford (1959) to differentiate subjects who were able to detect very small amplitude changes presented periodically in a pure tone signal. Here, 1dB increments are superimposed on a sustained tone of the aame frequency at an intensity level of 20dB above the person's threshold understudy. The score derived from this test reflects the percentage of 1dB increments heard by the listener.

Jerger (1962) found that average normal ear is least sensitive to 1dB increments at 20dB SL. For persons with normal hearing and conductive loss scores were obtained between 0% and 20% and scores between 60% and 100% (above 1KHz for patients with cochlear pathology.

Harris (1963) reports that 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.

A detailed study on the various aspects of the SISI was done by Yantis and Decker (1964) and they found that sensitivity to amplitude even of the small size 1dB 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 1dB increment. Their study indicates that a few normal hearing individuals do have relatively keen sensitivity to the small increments used in the test. 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. They found a tendency of SISI scores to cluster at extremes of the continuam and concluded that the test may be safely reduced to ten increments in many cases.

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

Swisher* Stephens and Doehring (1966) in the results of their study indicated that the SISI score* is influenced by both the hearing threshold level of the earrier tone and normal variability in differential sensitivity. Normal and nonadapting sensorineural impaired ears discriminated a signal of 1dB or less equally well at equivalent SPL. Swisher (1966) and Swisher et al (1966). While studying the effects of increasing sensation level on SISI scores Swisher, Stephens and Doehring (1966) suggested that SISI test might be interpreted as an indirect measure of bone conduction threshold.

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

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

It has been reported by Harbart. Young and Weiss (1969) that recruiting ears and normal ears perceive intensity increments of equal size at equivalent SPL. Low SISI scores were obtained when the subject received signal at 55 dB SPL or below. Harford (1965) and Harbert, Young and Weiss (1969) emphasize that SPL rather than SL is the important parameter in determing the score value. when the percentage scores in coaductively deafened ears are blotted after subtracting the conductive barrier these ears show an abrupt changes SISI scores at 60dB. This change was noticed at 50d8 SPL by trained normal listeners. It appears that subjects who undergo repeated testing or are acuite observes may also respond with high scores at this level and above.

When the SISI test was performed at the same SPL in the normal ear as 20 dB SL in pathological ears scores were identical i.e. both the normal and affected ear (cochlear impaired ear) (Martin, 1970).

Study by Rubinstein et al (1970) showed that 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:

i) the magnitude of the increment
ii) the SL of the carrier tone and
iii) the percentage of correct response

Various combination of these three variables will help in differentiation.

Study by Frederic Martin and Sales (1979) showed that normal ears did not give high scores as the SISI test when tested at the same loudness as pathological ears. They found that when normal ears receive the same SPL as 20dB 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 the tone decay increased the SISI score decreased in the bad ear. Results showed that high SISI scores begin to occur in the good ear somewhere between 55 and 65dB SPL. subjective loudness does not explain performance on 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.

Pushpa (1974) found that majority of normals obtained 100% SISI scores at 6Sda HL. Fulton and spradlin reported that SISI scores increased with practice and increased SISI scores persisted after 3 weeks of no practice, increased SISI scores were net a function of frequency.

An indirect procedure to estimate bone conduction threshold . for middle ear pathology patients was described by the Vincent W.Byers in (1974) and technique is known as "conductive SISI test".

A series of SISI tests are run beginning at 20dB SL and increasing in 10dB SL steps until a 100% SISI score is obtained. Following equation was given to predict the bone conduction threshold.

BCdB- 60dB + Air conduction (dB) - HL 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. It was reported that there was no statistical difference between the predicted thresholds and measured bone conduction thresholds for the group.

# METHODOLOGY

# METHODOLOGY

## Procedure:

Following steps were undertaken to conduct this study:

1. To obtain pure tone air-conduction and bone-conduction thresholds for all the subjects.
2. To find the hearing level at which 100% SISI results were obtained in normal hearing subjects.
3. To find the hearing level at which 100% SISI results were obtained in clinical group subjects (conductive hearing loss and sensorineural hearing loss) and to calculate the bone conduction threshold as suggested by Vincent W Byers (1974).

The frequencies tested for screening were 250Hz, 500Hz, 1000Hz, 2000Hz and 4000Hz in normal hearing subjects and also in clinical groups and 100% SISI results were obtained for 250Hz and 500Hz.

## Subjects:

Two groups of subjects were selected for the present study. 15 normal subjects with normal hearing threshold of 20 dBHL (ISO 1964) or less than 20 dBHL (ISO 1964) in both the ears were taken. The second group was consisted of '5' moderate conductive hearing loss subjects of various pathological conditions such as serous otitis media, ossicular rupture, dry perforation, etc. and '5' moderate sensorineural hearing loss subjects. Only right ear was considered for both normal hearing subjects and for the clinical group (conductive hearing loss subjects and sensorineural hearing loss subjects).

Equipment and test environment:

A calibrated GSI-16, audiometer was used to get air-conduction thresholds, bone-conduction thresholds and to administer SISI test. Audiometer was calibrated using Bruel and Kjaer instruments. The calibration was checked at regular intervals.

Two-room situation and sound treated rooms were utilized for the entire testing. The noise levels in the audiometric rooms were satisfactory according to proposed standard (ISO-1964) specifications.

Test Procedure:

Pure tone air conduction thresholds, bone conduction thresholds, and hearing level at which 100% SISI score results were found out for all the subjects. Carhart and Jezger's (1959) method of determining thresholds was used. Otological examination before the testing was done for all the subjects. While testing, intensity of carrier tone was raised whenever the subjects failed to response for 1dB increments. The hearing level at which the subject gives 100% SISI score was found out.

After getting air conduction thresholds and the hearing level at which 100% SISI was obtained, the bone conduction thresholds were calculated by using the formulas:

At 250Hz: BCTH-45 dB + air conduction(dB)-Hearing Level (dB) (100% SISI).

At 500Hzt BCTH-50 dB + air conduction(dB)-Hearing Level (dB) (100% SISI).

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

Instructions were given before doing pure tone audiometry and also for SISI.

Instructions for Pure Tone Audiometry:

"You will hear tone ia your ear either through the ear-phone or through bone conduction vibrator. Only one ear will be tested at a time". whenever you hear the tone, indicate by raising your finger. If you hear in right ear, raise your right hand finger, if your hear in left ear, raise your left finger. The moment you hear the tone; raise your finger and the moment you stop hearing, drop your finger. Response even for the very faint sound. Listen to the tone carefully.

In the case of SISI test; to familiarise the subject with tone, five practice events of 5dB, 4dB, 3dB, 2dB and 1dB increments were given. Then ten ldB increments were presented superimposed oa a sustained tone. A control event of OdB or 5dB was given randomly depending upon the subjects response to check false positive or false negative responses. The hearing level at whith the subjects could detect all the ten increments were found out.

Instructions for SISI Test:

You are going to hear a continuous tone in your ear. In the presence of the tone keep your finger raised. There will be jumps in the loudness of the tone sometimes. Flicker your finger even if the jump in loudness of the tone is very small, don't flicker your finger in the absenace of the jump, in the loudness of the tone.

# RESULTS

# RESULTS

The present study was aimed to compare the bone conduction thresholds at 250Hz and 500Hz by conventional method and conductive SISI method aa suggested by Byer, 1974.

Table-I shows the intensity level in dB which 100% SISI scores occurs in normals at 2dB increment at 350Hz and 500Hz. The mean threshold at 250Hz and 500Hz are 45dB and 50dB respectively.

Table-II shows the bone conduction thresholds for normals at 250Hz and 500Hz by conventional method. The bone conduction thresholds through conductive SISI were Obtained as follows:

i) At 250Hz

BC dB = 45dB + Air Conduction (dB) - Hearing Level dB (100% SISI)

ii) At 500Hz

BC dB = 50dB + Air Conduction (dB) - Hearing Level dB (100% SISI)

Table-III shows bone conduction thresholds for normals at 250Hz and 500Hz by conductive SISI method.

Table-IV shows the bone conduction thresholds for clinical population at 250Hz and 500Hz by conventional and conductive SISI method.

The statistical analysis was done to examine the significant difference between the bone conduction thresholds by conventional and conductive SISI method using Mann-Whitney 'U' test.

Table-V shows the results of Mann-Whitney 'U' test. It is evident from Table-V that there is no significant difference between the bone conduction thresholds obtained through conventional method and conductive SISI method at 250Hz (U = 108) and 500Hz (U = 112) at .01 and 0.05 level of significance among normals.

The significant difference was observed among conductive hearing loss group at 500Hz (U = 4) at .05 level but not at .01 level. This may be due to sampling errors. However no significant difference was seen at 250Hz (U = 12) at .05 and .01 level.

There was no significant difference observed between sensory neural hearing loss group at 250Hz (U = 8) and 500Hz (U = 12.5) at .05 and .01 level.

Table-I showing intensity level in dB at which 100% SISI scores occurs in normal at 250Hz end 500Hz.

| Subject | Level in dB | |
|---|---|---|
| | 250Hz | 500Hz |
| 1 | 50 | 65 |
| 2 | 45 | 50 |
| 3 | 45 | 55 |
| 4 | 45 | 50 |
| 5 | 45 | 50 |
| 6 | 45 | 55 |
| 7 | 50 | 55 |
| 8 | 45 | 55 |
| 9 | 50 | 55 |
| 10 | 40 | 50 |
| 11 | 45 | 50 |
| 12 | 45 | 35 |
| 13 | 45 | 55 |
| 14 | 45 | 50 |
| 15 | 40 | 50 |
| Mean | 45 dB | 50 dB |

Table-II: Showing Bone Conduction thresholds for normals at 250Mz and 500Hz by conventional method

| Subject | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 250Hz | 5 | 15 | 5 | 10 | 0 | 10 | 10 | 10 | 15 | 0 | 10 | 5 | 5 | 5 | 15 |
| 500Hz | 10 | 10 | 10 | 10 | 5 | 0 | 10 | 0 | 15 | 0 | 5 | 5 | 0 | 0 | 15 |

Table-III Showing Bone Conduction thresholds for nomals at 250Hz and 500Hz by conductive SISI method.

| subject | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 250Hz | 10 | 15 | 5 | 10 | 0 | 10 | 10 | 10 | 5 | 5 | 10 | 5 | 10 | 5 | 15 |
| 500Hz | 5 | 10 | 10 | 10 | 5 | 0 | 10 | 0 | 5 | 5 | 10 | 5 | 0 | 5 | 15 |

Table-IV: Showing Bone Conduction thresholds for clinical population at 250Hz and 500Hz by conventional and conductive SISI method

| Frequency | Subject | Conductive loss (Group-I) | | Sensorineural Loss Group-II) | |
|---|---|---|---|---|---|
| | | Conventional method | Conductive SISI | Conventional method | Conductive SISI |
| 250HZ | 1 | 5 | 0 | 50 | 50 |
| | 2 | 15 | 25 | 40 | 40 |
| | 3 | 5 | -10 | 40 | 35 |
| | 4 | 15 | 10 | 40 | 35 |
| | 5 | 15 | 25 | 33 | 30 |
| 500Hz | 1 | 5 | 20 | 55 | 55 |
| | 2 | 5 | 5 | 40 | 40 |
| | 3 | 10 | 25 | 30 | 40 |
| | 4 | 10 | 20 | 45 | 50 |
| | 5 | 15 | 25 | 40 | 45 |

Table-V: showing the critical value of U test at 250Hz and 500Hz among normals and clinical population.

| Frequency | Normals | Conductive hearing lees group | Sensoiineural hearing less group |
|---|---|---|---|
| 250Hz | 108 | 12 | 8 |
| 500Hz | 112 | 4 | 12.5 |

# DISCUSSION

# DISCUSSION

Byers (1974) described "Conductive SISI" test, an indirect procedure to estimate bone-conduction thresholds for middle ear pathology patients where actual determination through conventional method is not possible or where the bone conduction threshold is questionable. A series of SISI teat are run beginning at 20dB SL and increasing in 10dB SL step until a 100% SISI scores is obtained using 1dB increment. He gave the following equation to predict the bone conduction thresholds.

BC dB - 60dB + Air Conduction (dB) - Hearing Level dB(100% SISI)

Narendran (1975) verified the usefulness of conductive SISI test as described by Byers (1974) on normals aad on clinical population.

The purpose of the present study was to examine the effectiveness of conductive SISI test among normals and clinical population at lower frequencies i.e. 250Hz and 500Hz, using 2dB increment. 15 normals 5 moderate conductive hearing loss patients, and 5 moderate sensory neural hearing loss patients served as the subjects. Hearing level at which 100% SISI scores occurs is determined for each subject at 250Mz and 500Hz using 2dB increment. Bone conduction thresholds through conductive SISI test were obtained by using following formulas.

At 250Hz:

BC dB = 45dB + Air Conduction(dB)-Hearing Level dB(100% SISI)

At 500Hz:

BC dB - 50dB + Air Conduction(dB)-Hearing Level dB(100% SISI)

Where 45dB and 50dB are mean valuea of hearing level at which 100% SISI scores results using 2dB increment at 250Hz and 500Mz respectively.

The result of the prevent investigation clearly indicated that there is no significant difference in bone conduction thresholds obtained through conventional method and conductive SISI method among normals and Clinical population at 250 and 500Hz, except for conductive hearing loss patienta at 500Hz (at .05 level) which may be because of small fluctuations in human performance or due to sampling or measurement errors.

The result of this investigation are in general agreement with the earlier studies which have been reported in the literature.

Byers (1974) reported no statistical significance difference between the bone conduction thresholds measured through conventional and conductive SISI method is a group of 25 hearing loss patients.

Narendran (1975) repotted no significant differennce in bone conduction threshold by both conventional and conductive

SISI method at 500Hz, 1000Hz, 2000Hz and 4000Hz for mixed hearing loss and sensorineural hearing loss group and except at 2000Hz for conductive hearing loss group. The difference in bone conduction threshold by these two methods at 2000Hz may be attributed to Cazhart's notch.

Implications for future research:

True bone coadaction thresholds can be obtained using conductive SISI test where the determination of bone conduction threshold ia difficult to obtain or when threahoida by ceaven-tional method in questionable. Conductive SISI test may give better picture about the cochlear reserve in mixed hearing loss cases which will help in selection of cases for surgery.

# SUMMARY AND CONCLUSION

## SUMMARY AMD CONCLUSION

The present study was aimed to examine the significant difference between the bone conduction thresholds obtained through conventional method and conductive SISI test.

15 normals, 5 conductive hearing loss cases and S sensori-neural hearing loss cases were tested to find the bone conduction threshold through above two methods.

### Conclusion of the study:

1) 100% SISI is observed at 45dB HL (mean value) at 25OHz and 50 dB HL(mean value) at 500Hz in normal hearing subjects.
2) There is no significant difference in bone conduction thresholds by both conductive SISI and conventional method.

### Limitations of the study:

1) The study is limited to two frequencies i.e. 250Hz and 500Hz.
2) The number of subjects in clinical group were small.
3) Different middle ear pathological conditions have not been studied separately.

### Recommendations For Future Research:

1) Different middle ear pathological conditions i.e. otosclerosis. otitis media can be studied extensively.

2) Bone conduction thresholds at 250Hz using conductive SISI test may help ia differentiating pseudo bone conduction thresholds and real bone conduction thresholds in severe hearing loss cases.
3) Conductive SISI test at high frequencies i.e. 6000Hz and 8000Hz can be studied in conductive high tone loss cases to get the bone conduction thresholds.

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