EFFECTIVENESS OF DPOAE AND TEOAE IN HEARING SCREENING

Reg.No. 02SH0001

Independent Project submitted in part fulfillment for the
First year M.Sc, (Speech and Hearing)
University of Mysore, Mysore

ALL INDIA INSTITUTE OF SPEECH AND HEARING
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JUNE-2003

CERTIFICATE

This is to certify that this Independent Project entitled **"EFFECTIVENESS OF** DPOAE AND TEOAE IN HEARING SCREENING" is abonafide work in part of fulfillment for the degree of Master of Science (Speech and Hearing) of the student **(Register No. 02SH0001)**

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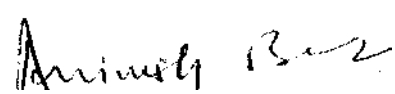
CERTIFICATE

This is to certify that this Independent Project entitled **"EFFECTIVENESS OF DPOAE AND TEOAE IN HEARING SCREENING"** has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in any other University for the award of any diploma or degree.



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DECLARATION

This Independent Project entitled **"EFFECTIVENESS OF DPOAE AND TEOAE IN HEARING SCREENING"** is the result of my own study under the guidance of **MR. ANIMESH BURMAN,** Lecturer in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore and not been submitted in any other University for the award of any degree or diploma.

Mysore,

June, 2003 **Reg. No. 02SH0001**

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INTRODUCTION

Hearing is defined as the sense, receptive in nature through which spoken language is received by response to sound pressure waves. The ears, the auditory nerve and the brain are involved in the process of hearing.

Auditory channel is the route through which speech and language development usually takes place and hearing is necessary to monitor one's own production of speech and language. A child born with hearing loss will have impaired development of speech and verbal language skills.

It is well known that undetected hearing loss in children can lead to delay in speech and language development, academic deficiencies, and possible social or emotional difficulties. It has been reported that many children with congenital severe to profound hearing loss are often not identified until they start to attend school (National Center For Health And Management, NCHAM, 1999).

First three years are critical in development of speech and language skills and hearing impairment at that time would effect this development. Even an acquired loss in children can lead to deterioration of existing speech skills. The impact of ignoring a hearing impairment in an elderly person may extend beyond the simple inability to hear. Indeed, the neglected hearing loss may contribute to a diminished overall quality of life for the elderly person. Thus one should not be careless about it.

The earlier the loss is identified, the gap to be bridged is less, and the rehabilitation process takes lesser time and effort. The importance of hearing integrity in the first 3-4 years after birth for normal acquisition of speech and language has long been appreciated (Lenneberg, Rebelsky & Nichols, 1967). Several studies show that early diagnosis of hearing impairment in children leads to obvious advantage with regard to habilitation [Greenstein, Greenstein & McConville; Greenberg; Markides; Ramkalawan & Davis (cited in Magnouson, & Hergils, 1999); Mauk & Behrens, 1993; Apuzzo & Yoshinaga-Itano, 1995; Robinshaw (cited in Magnouson, & Hergils, 1999)].

During this sensitive (often called "critical period") period, speech and language will almost always develop rapidly and normally, if the auditory and language regions of the brain are adequately stimulated.

Therefore hearing impairment should be recognized early so as to take full advantage of the plasticity of the developing sensory system. If left undetected, hearing impairments in infants can negatively impact speech and language acquisition, academic achievements, and social and emotional development. If detected, however, these negative impacts can be diminished and even eliminated through early intervention. Because of this, the National Institute of Health (NIH) Consensus Development conference on early identification of hearing loss (1993) concluded that all infants should be screened for hearing impairment.

Hearing screening provides a quick, cost effective way to determine whether in depth evaluation by an audiologist is needed. Screening, as accepted by WHO is

defined as " the presumption recognition of unrecognized disease of defects by the application of tests, examination and other procedures, which can be applied rapidly."

Auditory screening is an attempt to identify persons who have significant hearing defects, from a population of predominantly people with normal/adequate hearing (Hedgecock, Miller & Rose, 1973).

Hearing screening tests are administered in either individuals or group settings. Earlier the stimuli used in these tests for screening range from pure tones and speech to noise produced by various noisemakers, squeakers and environmental sounds (Anderson, 1972).

There are a variety of methods that can be utilized in hearing screening (Martin, 1977; McCormick, 1986; Northern & Downs, 1991). These include:

a) Behavioral tests

b) Objective tests

Behavioral tests involve careful behavioral observation and assessment of unconditioned or conditioned responses given by a subject, which are active responses to the presence of a sound stimulus (Northern & Hayes, 1996). There can be wide variance in the responses obtained, from a mere eye blink to head turn in the direction of source (Northern & Downs, 1991). Tester bias is seen in these tests, interpretation of the responses depends on the clinician's experience. There can be more chances of obtaining false positive and false negative responses (Fainmesses & Tell, 1976; Wharrad, 1988) leading to either over referral or under referral of such population.

Objectives tests are non-behavioral methods to assess the hearing status. Objectives tests can be physiological or electro-physiological methods, like auditory brainstem response, otoacoustic emission, immittance evaluations etc. that do not require active participation from the subject. Hence objectives tests can give more reliable results.

The main disadvantages of ABR testing are:

- The relative maturity of the central auditory nervous system can affect the auditory brain stem responses
- ABR is a time consuming test.
- Electrical shielding is important for ABR recording.

OAE is another widely used objective tool for screening. In contrast to ABR, OAE is less time consuming, cost effective and does not require the maturation of central nervous system. OAE's are sound generated within the cochlea by the outer hair cells, as outer hair cells are fully maturated at the time of birth.

Two types of OAE's are widely used for screening, which are

DPOAE

TEOAE

Well-developed DPOAEs have been observed in neonates (Samurzynski, Leonard, Kim, Lafreniere & Jung, 1990). DPOAEs are found to be present in 100% of the normal population (Johnsen, Bagi & Elberling, 1983; Elberling, Parbo, Johnsen & Bagi, 1985). It is well established and promises to be an excellent clinical tool for hearing screening purpose (Probst & Harris, 1993).

The most widely used EOAE technique is the TEOAE (White, 1996). TEOAE can be elicited in nearly all individuals with hearing sensitivity better than 25-35 dBHL (Kemp, 1978; Stevens, 1988). Unlike ABR, TEOAEs appear to be an "all-or-none" response i.e. a TEOAE will most likely be elicited in any frequency region in which an infant has normal hearing. TEOAEs can be measured in more than 90% of all the subjects with normal hearing. This important feature contributes to the clinical relevance of the TEOAE (White, 1996).

Need For The Study: -

Screening is very important for early detection of hearing problem. If hearing loss is left undetected, it could lead to delayed speech and language development or several other problems like academic failure, emotional problems etc. OAEs are a good screening tool as they are non-invasive, objective and can screen the individual without any active participation of the client. Among the several objective test OAEs especially TEOAE and DPOAE measurement have gained a wide popularity due to its cost effectiveness, time taken and reliability of the test results. Between the two OAE tests, TEOAE seems to have gained more popularity than DPOAE.

Though TEOAE is most widely used for hearing screening, it is not present in 100% of the normal population, resulting in over referral. However, DPOAE is present in 100% of the normal population, hence the chance of over referral is ruled out.

However, TEOAE measurements are more sensitive to hearing sensitivity. It may not be present in a person with minimal to mild hearing loss whereas DPOAE can be seen even in a person with moderate hearing loss, in turn leading to increase in number of people passing the screening. Thus, it is difficult for one to say which is more effective. It is learned that the screening programs is not identifying deaf infants very successfully and that the large number of false positive responses cause unnecessary parental anxiety and cost a lot of time and money. Thus research should be carried out to identify such screening methods, which will enable us to reduce the false positive and false negative responses and also unnecessary anxiety to the parents and individuals. Keeping these facts in mind, this study intends to find out the efficiency of TEOAEs and DPOAEs as a tool for hearing screening.

Aims of The Study to Investigate The: -

- Effectiveness of TEOAE and DPOAE in hearing screening,
- The sensitivity and specificity of TEOAE and DPOAE and
- Cost effectiveness of each procedure.

REVIEW OF LITERATURE

Screening is the process of applying certain rapid and simple tests, examination or other procedures to generally a large number of persons that will identify those people with a high probability of the disorder from those persons who probably do not have the disorder. A certain measurement cut off point is always involved, below or above which the persons are at risk. Those who are identified with positive or suspicious findings must be referred for detailed evaluations and interventions (Northern & Downs, 1978).

The purposes for screening are to identify those with hearing disorders that may need medical attention and also to identify those who may have impairment and need non-medical remediation so that they may receive the help they need. Therefore, a screening protocol should provide checks for medical concerns as well as communication and social/emotional issues related to hearing (Hood & Berlin, 1986).

Since hearing impairment is relatively invisible, hearing screening tests have been in use for at least sixty years to identify children for further auditory evaluation. Hearing screening programs have been established in an effort to identify the early presence of hearing loss. So that habilitative measures can be instituted as early as possible (Northern & Downs, 1978).

Subsequently in 1970, a Joint Committee of American Speech and Hearing Association, AAOO and American Academy of Pediatrics (cited in Northern &

Hayes, 1996) recommended that routine screening program be discontinued. They urged that controlled experimental programs continue to investigate useful stimuli, response patterns, environmental factors, and status of neonate during behavioral testing. In a supplementary statement in 1969 The Joint Committee recommended the use of high-risk register to identify neonates in whom the probability of hearing loss could be expected to be higher than normal. A five-point identification high-risk register represented by Simple mnemonic "the ABCDs of deafness" (Downs & Silver, 1972) came into application.

High Risk Register (HRR) is a questionnaire-based method with which one can identify small group of children whose history or physical condition identifies them as possessing a high chance of having the handicap being searched for (Northern & Downs, 1978). Mahoney and Eichwald (1979) reported sensitivity and specificity of High Risk Register as 65% and 75% respectively.

Risk register was reported as an effective newborn screening tool, which played an important role in the identification of many hearing, impaired infants during the post 1970s (Pappas, 1983; Stein, Clark & Kraus, 1983; Elssman, Markin & Sobo, 1987; Stein, Jabaley, Spitz, Stoakley & McGee, 1990; Mauk, White, Mortensen & Benerm, 1991). By early 1980's it became clear that approximately half of the children who were eventually diagnosed with communicatively important, permanent, sensori-neural hearing impairment were, in retrospect, born as healthy infants, with none of these risk indicators (Pappas, 1983; Stein, Clark & Kraus, 1983; Elssman, Markin & Sobo, 1987; Stein, Jabaley, Spitz, Stoakley & McGee, 1990; Mauk, White,

Mortensen & Benerm, 1991). In the early 1990's, however evidence from numerous studies confirmed that the use of the High risk register as the basis of infant hearing screening program identified only 50% of infants with significant hearing loss (Pappas, 1983; Elssman, Markin & Sobo, 1987, Stein, Jabaley, Spitz, Stoakley & McGee, 1990; Mauk, White, Mortensen & Benerm, 1991).

Screening over the years has been done using either subjective or objective procedure or a combination of the two procedures. Either a single procedure has been made use of or two and more procedures for comparisons in terms of different aspects.

Subjective Procedure: -

There are a variety of subjective methods that can be utilized in hearing screening. One of the methods is behavioral observation audiometry, an other method is Pure Tone Audiometry. Since these tests involve active participation of the subject, reliability of the test results becomes questionable especially in younger children. Besides, it is time consuming.

Behavioral observation audiometry is the oldest subjective procedure of hearing screening. Behavioral tests involve careful behavioral observation and assessment of unconditioned or conditioned responses given by a subject, which are active responses to the presence of a sound stimulus (Northern & Hayes, 1996).

Behavioral observation audiometry is usually done with noise makers, which are time and cost effective, and does not require extensive technical equipment. The

traditional tests for hearing screening of the infant after birth have been described by Sheridan (1957), Hardy, Dougherty and Hardy (1959), Northern and Downs (1978) and Ewing and Ewing (1994). All the tests involve observation of the infant's responses to selected noisemakers. Using behavioral techniques, Northern and Downs (1978) reported a false negative rate of 38% from the screening carried out on 10,726 infants.

Many studies have been done on pure tone measures as a tool for hearing screening. Eagles, Wisnik, Doerfler, Melnick and Levine (1963) noted in the Pittsburg study that conventional audiometry would reveal not only those with hearing loss, but also those with ear conditions needing medical care. However, their data indicated that audiometric testing may show the hearing to be normal even though the child may have physical abnormalities of the ear. According to Eagles, Wisnik, Doerfler, Melnick and Levine (1963), "the ramifications of this are enormous because it unequivocally demonstrates that audiometric testing alone will not screen out a child with significant percent of ear disease."

Melnick, Eagles and Levine (1964) screened eight hundred and eighty children from kindergarten through to the eight grades and found that hearing results for audiometric screening did not adequately identify children with otoscopic evidence of acute or past ear pathology.

Objective Procedure: -

Hearing screening has made dramatic progress with the more recent addition of impedance (Northern, 1977) as an adjunct to the individual pure tone sweep test,

which has been the most acceptable tool for hearing screening in the schools (Darley, 1961). Pure tone audiometry and impedance screening are said to be an ideal pair in identification Grosso and Rupp (1978).

Renvell, Liden and Jungert (1973) concluded that it is not wise to rely solely on impedance audiometry for screening purposes because many sensori-neural type of hearing losses would not be identified, and thus an impedance-screening test should be supplemented with pure tone audiometry.

Subjects in which it was difficult to obtain pure tone thresholds, ABR was done. ABR is a viable technique for infant hearing screening, even among premature neonates (Salamy, McKean & Buda, 1975; Schulman-Golambos & Galambos, 1975; Mokotoff, Schulman-Galambos & Galambos, 1977). Prior to the discovery and description of OAEs, auditory development was evaluated primarily via assessment of auditory behavior (Werner & Bargones, 1991; Werner & Macrean, 1991; Bargones, Werner & Macrean, 1995) or by means of auditory brainstem response (Salamy, Mendelson, Tooley, Chaplin, 1980; Starr & Amlie, 1981; Folsom, 1985; Klein, 1986; Collet, Delorme, Chanal, Dubrevil, Morgon & Salle 1987; Eggermont & Salamy, 1988). ABR provided valuable information regarding the development of hearing in the newborn period involving many levels of auditory systems, including the cochlea and neural structure; until unless these structures are developed we don't get accurate results (Abdala & Folsom, 1995).

Hearing screening program for newborns have used ABR as a measure that provides reliable information and results (Galambos & Hexon, 1978; Cox, Hack &

Metz, 1981; Galambos, Hicks & Wilson, 1982; Jacobson & Morevouse, 1984). ABRs with the use of frequency specific and bone conduction stimuli can provide information necessary to initiate appropriate management.

Galambos, Wilson and Silva (1994) screened 4374 infants using ABR at 30 dB nHL resulted in failure rates of 19.8%. The ABR does not truly assess hearing in the global sense. Absence of ABR alone cannot be interpreted as an infallible key of peripheral hearing loss.

The ABR is an objective measure in the sense that the subject need not voluntarily participate, but there is a subjective component in test interpretation. Also ABR instrument is very costly and can be time consuming. The maintenance cost of the instrument is also very high. Electrically shielded room is a must for ABR recording, which is less feasible especially in Indian conditions.

OAE can be measured in newborn quickly and non-invasively (Johnsen, Bagi & Elberling, 1983; Bonfils, Uziel & Pujol, 1988). OAE testing has many characteristics, which suit it for use as an objective auditory screening. The most important of these is the speed with which it can be performed. This feature alone opens up the possibility of much more general neonatal screening programs (Kemp & Ryan, 1991).

OAE were recommended as appropriate screening tool by Joint Committee on Infant Hearing (1994) and the American Academy of Pediatrics (1999). Better measurement can be made if the child is not moving or crying. However breathing

noise seems to be a major source of noise in newborn (White, Vohr & Behrens, 1993).

The advantage of OAE and its wide spread application, revolutionalised the area of auditory screening. TEOAEs especially were reached upon extensively by a number of investigators. Striking features of TEOAEs, which made it gain popularity, were faster procedure, good accuracy, lesser cost and higher sensitivity (White, Vohr & Behrens, 1993; Brass & Kemp, 1994; Aidan, Avan & Bonfils, 1999).

TEOAE was highly recommended as a screening tool. Though majority of the investigation agreed upon for TEOAE being one of the best screening procedures available, yet at the same time there were some others who differed in their viewpoint. The sensitivity and reliability of TEOAE was put to question when it was compared across ABR, behavioral threshold and also when follow-ups were done (Wood, Mason, Farnsworth, Davis, Curnock & Lutman, 1998). Most of the researchers agreed upon the fact that though ABR was expensive, it ensured better sensitivity than OAE. But no robust conclusions were made (Dort, Tobolski & Brown, 2000). Though ABR was agreed upon to be the good standard, TEOAE was accepted as a choice for universal screening. At the same time improvement for standardization of test had been recommended (Wood, Mason, Farnsworth, Davis, Curnock & Lutman, 1998; Paludetti, Ottaviani, Fetoni, Zuppa & Tortorolo, 1999).

Till late DPOAE, though found to be a promising technique (Salata, Jacobson & Strasnick, 1998) was not investigated as much as TEOAE in hearing screening. Though both TEOAE and DPOAE are similar in certain aspects of their application to

pediatric population, yet DPOAEs scored over TEOAEs in certain aspects. As seen by the studies reported above, OAE has been recommended as the primary screening tool by most of the researchers owing to feasibility in terms of time, cost and sensitivity.

Most of the recent studies that have been carried out make use of objective methods. The same trend can be followed in Indian setups if it is less costly and fast in screening. Hence, there is need for development of screening kit, which would take into consideration factors like cost, time, population (to be screened) without compromising much on sensitivity.

METHOD

The aims of the study were to check the efficacy, sensitivity and specificity of TEOAE and DPOAE and the cost effectiveness of each procedure in hearing screening. The method used to obtained data was as follows:

Subjects: A total of 484 ears were screened. The subjects were divided into three age groups i.e. below 3 years, 3 to 15 years and above 15 years of age. Forty-two ears of the children below 3 years were screened. In the age range of 3 to 15 years 246 ears were screened and above 15 years of age 196 ears were screened.

Selection criteria: Patients, parents and friends, who had either come for assessment or accompanied the patients at AIISH, were randomly considered for the study in all age groups, irrespective of whether they had a history of hearing loss or not. Subjects who reported to have any visible ear abnormality, ear discharge were not taken for the study. Otoscopic examination was carried out prior to OAE measurement. Individual with wax in the ears were also not considered.

Instrumentation: The following equipments were used for screening: -

a) Otoacoustic Emission: For measuring DPOAE and TEOAE, ILO-296 DP Echoport was made use of.

b) Pure Tone Audiometry: Calibrated clinical audiometer OB-922 with TDH-39 headphone was used to assess hearing sensitivity of the subjects frequencies ranging from 250 Hz to 8 KHz.

Behavioral Observation Audiometry was done using frequency modulated tone at 500 Hz to 4 KHz for whom pure tone thresholds could not be obtained.

c) Immittance: Immittance meter GSI-33 (version 2) was made use of to assess the middle ear status.

d) Auditory Brainstem Response: Nicolet Bravo was used to estimate threshold using ABR measurement for those subjects for whom pure tone thresholds could not be obtained.

Test Environment: For detailed assessment testing was carried out in sound treated rooms. OAE screening was carried out in less noisy rooms to match the screening situation during field visit.

Procedure: -

a) OAE: The following is the procedure for OAE screening.

Preparation of the subject:

First the subject's ear canal was examined for the presence of wax or debris. An appropriate tip was selected and installed on the probe. The subject's pinna was pulled backwards and upward to straighten the ear canal, following which the probe was inserted. Care was taken to minimize subject's body movements during OAE measurement. For DPOAE, six frequencies i.e., 1, 2, 2.5, 3, 4 and 6 kHz and TEOAE for clicks (five-frequency band i.e., 1, 1.5, 2, 2.8 and 4 kHz) were recorded.

b) Pure Tone Audiometry: PTA was carried out on each subject using calibrated audiometer. The subjects were instructed to raise their finger whenever they hear the sound in case of adults and in case of children they were told to place the blocks on

the table, when the sound is heard by them. In case of children conditioning was done prior to pure tone audiometry.

In children below 3 years of age where pure tone thresholds could not be obtained, BOA was carried out at frequencies from 500 Hz to 4 kHz in octaves.

c) Immittance: Later immittance audiometry was carried out. An appropriate tip was selected and installed on the probe. The procedure to fit probe tip was same as that of OAE, but the type of tip used was different. Each ear of the subject was tested for type of tympanogram and presence or absence of reflexes.

d) **ABR:** ABR was recorded on children where pure tone thresholds could not be obtained.

Children were first given the sedation and then the electrodes sites i.e., mastoid and forehead were cleaned using skin preparatory gel. Electrodes were then placed carefully, so as not to wake up the child. Finally headphone was placed and threshold was obtained using clicks. The stimulus used to elicit ABR was clicks at variable intensity. Non-inverting electrodes were placed on the forehead and test ear mastoid was inverting and non-test ear mastoid being the common. An attempt was made to keep the individuals electrical impedance within 5 KX2 and inter-electrode impedance within 2 KX2 to get reliable response.

Response criteria: -

a) **OAE:** The instrument automatically displayed whether the individual has passed or failed depending on the emission measure.

b) **Diagnostic Testing:** Absent reflexes and tympanograms with B, C and other types (D or E) along with pure tone threshold more than 15 dB was considered as fail. Tympanogram of A, As and Ad type with reflexes present and pure tone threshold less than 15 dB was considered as pass. In case of children below three years of age those who had ABR responses at 30 dBnHL and BOA responses at around 30 to 40 dBHL were considered as pass.

Analysis: -

Statistical analysis using Phi coefficient was carried out to find the correlation between the three procedures i.e., Diagnostic tests, DPOAE and TEOAE. Test of significance for the coefficient was also done.

Sensitivity and specificity of the two procedures were also compared with respect to diagnostic findings. The procedure to calculate sensitivity and specificity adopted by Dort, Tobolski, Brown (2000) was used for this study.

x

RESULTS AND DISCUSSION

This study was carried out to find out the effectiveness of DPOAE and TEOAE in hearing screening. Phi-correlation and significance of the correlation of TEOAE and DPOAE with respect to diagnostic test was calculated. Procedures were compared across groups. The results are as follows:

Group I: Below 3 years: -

Table l(a): Represents the numbers of pass and fail between two tests.

Test		DPOAE		TEOAE		Total
		Fail	Pass	Fail	Pass	
Diagnostic Test	Fail	37	1	37	1	38
	Pass	4	-	3	1	4
	Total	41	1	40	2	42
DPOAE	Fail	-	-	40	1	41
	Pass	-	-	-	1	1
	Total	-	-	40	2	42

Table l(b): Represents the Phi-correlation values and approximate significance level of Phi.

Test	**DPOAE**		TEOAE	
	Value	Approx. Sig.	Value	Approx. Sig.
Diagnostic Test	-0.05	.743	.308	.046
DPOAE	-	-	**.698**	.000

From the tables l(a) and l(b), it can be clearly seen that about 37 ears tested out of 42 ears failed both in the diagnostic tests and DPOAE test. Discrepancy can be seen only in 5 ears, which indicates poor correlation between the tests.

A significant low positive correlation was obtained when the diagnostic test was compared to TEOAE as 37 ears out of 42 ears tested failed in both the tests and discrepancy was found in only 4 ears tested.

Highly significant positive correlation was found when DPOAE was compared with TEOAE as 40 out of 42 ears tested failed in both the tests, one passed in both the tests and discrepancy was seen in only one ear tested.

Group II: 3-15 years: -

Table 2(a): Represents the numbers of pass and fail between two tests.

Test		**DPOAE**		**TEOAE**		**Total**
		Fail	**Pass**	**Fail**	**Pass**	
Diagnostic Test	Fail	123	14	129	8	137
	Pass	11	98	17	92	109
	Total	134	112	146	100	246
DPOAE	Fail	-	-	131	3	134
	Pass	-	-	15	97	112
	Total	-	-	146	100	246

Table 2(b): Represents the Phi-correlation values and approximate significance level of Phi.

Test	**DPOAE**		**TEOAE**	
	Value	**Approx. Sig.**	**Value**	**Approx. Sig.**
Diagnostic Test	.795	.000	.795	.000
DPOAE	-	-	.855	.000

It is evident from tables 2(a) and 2(b) that all the three procedures are in good agreement with each other. High significant correlation was seen when all the tests were compared with each other.

Out of 296 ears tested, 123 ears have failed in both diagnostic test and DPOAE measurements. Discrepancy between the two tests results were seen in 25 ears tested where as 129 ears have failed in both the diagnostic test and TEOAE measurements. 92 ears have passed and discrepancy in results is seen only in 25 ears between the two test results. Again a very good agreement was seen when DPOAE was compared with TEOAE as 131 ears out of 246 ears tested failed in both the tests, 97 ears out of 246 ears passed in both the tests and discrepancy was found on 18 ears tested, thus showing high positive correlation between any two test results.

Group III: **Above 15 years: -**

Table 3(a): Represents the numbers of pass and fail between two tests.

Test		**DPOAE**		**TEOAE**		**Total**
		Fail	**Pass**	**Fail**	**Pass**	
Diagnostic Test	Fail	77	12	82	7	89
	Pass	3	104	9	98	107
	Total	80	116	91	105	196
DPOAE	Fail	-	-	*16*	4	80
	Pass	-	-	15	101	116
	Total	-	-	91	105	196

Table 3(b): Represents the Phi-correlation values and approximate significance level of Phi.

Test	DPOAE		TEOAE	
	Value	**Approx. Sig.**	**Value**	**Approx. Sig.**
Diagnostic Test	.848	.000	.836	.000
DPOAE	-	-	.809	.000

A total agreement between the diagnostic tests, DPOAE and TEOAE results can be seen from the tables 3(a) and 3(b). While comparing diagnostic tests results with DPOAE measurements, it was found that 77 ears out of 196 ears tested failed in both the tests, 104 passed in both the tests and only 15 ears showed discrepancy between the tests, hence showing a significantly high positive correlation.

Out of 196 ears tested, 82 ears failed in both the tests, 98 passed in both tests and discrepancy could be seen only in 16 ears when diagnostic test was compared with TEOAE result seen to have a high positive correlation which is same as seen between the diagnostic tests and DPOAE findings.

A highly significant correlation is expressed when DPOAE is compared with TEOAE results, out of 196 ears tested 76 ears failed in both the tests, 101 passed in both the tests and 19 showed discrepancy between the tests, thus resulting in high significant positive correlation.

The present study investigates the usage of OAE in hearing screening versus diagnostic tests i.e. pure tone audiometry, ABR and immittance test results.

It can be noted from the results that all the procedures have significantly good correlation in group II and III. This can be explained by a number of reasons. First, that both the diagnostic test and OAE test (TEOAE and DPOAE) was carried out in sound proofrooms. Secondly, the body movements affect OAE's and . it will be more affected in fully awake alert children. But in the present study most of the children ' were screened while they were either asleep or very co-operative, thus body movements were negligible. In spite of the physiological noise, OAE's could be obtained in the young children. Amplitude of OAE in younger group has also been reported to be higher (Smurzynski, Jung, Lareniere, Kim, Kamath, Rowe, Holman & Leonard, 1993), thus modifying the effect of physiological noise.

However, the agreement between the diagnostic test result and TEOAE and DPOAE findings had relative poor positive correlation in Group I. This may be due to number of ears tested in this group is very less in comparison to other groups. That is why having less number of discrepancies in results obtained between the two tests in comparison to other groups, had poor correlation, where as in older groups subjects were co-operative, and relaxed and less physiological noise, resulting in better OAE measurement. Thus, it increased the reliability of OAE measurement due to which there is very good agreement between the OAE and Diagnostic test results.

The results of over all distribution of the ears tested showed a highly significant agreement for all the tests done i.e. diagnostic test vs. TEOAE, Diagnostic test vs. DPOAE and TEOAE vs. DPOAE in all the three age groups. Diagnostic test

vs. TEOAE was seen to have slightly better correlation than the other two tests. This shows that there exists a definite agreement for diagnostic test and OAE screening and best agreement between the both OAE measures.

In some ears tested, slight discrepancy between TEOAE and DPOAE tests were noted. There is a growing concern regarding the agreement of test outcomes among different TEOAE pass/fail criteria (Dircks, Daemers, Somers, Offeciers & Govaerts, 1996) and between the TEOAE and DPOAE measures (Gorga, Neeley, Bergman, Beauchaine, Kaminski, Peters, Schulte, & Jesteadt, 1993).

On comparison with ABR for its efficiency as a tool for identification of hearing loss, DPOAEs were found to have similar test performance, though perfect test performance had never achieved. Sensitivity for each measures increased with the magnitude of hearing loss (Norton, 2000). DPOAEs were also found to correspond well with behavioral audiometric thresholds (Harris, 1990; Probst & Harris, 1993). Most of the researchers agreed upon the fact that DPOAEs are strong and can be detected in almost all normal hearing subjects (Probst, Lonsbury-Martin & Martin, 1991). Franklin, McCoy, Lonsbury-Martin and Martin (1992) studied the test-retest reliability of DPOAE in normal human ears. They concluded that the consistency of repeated measures of DPOAEs was generally excellent, particularly within the mild to high frequency range (2000 Hz to 8000Hz). Thus, suggesting DPOAE could be a better tool for hearing screening.

Sensitivity and Specificity: -

Table 4: Represents the sensitivity and specificity

	< 3 years		3-15 yrs.		Above 15 yrs.		Over all	
	Sens.	**Spec.**	**Sens.**	**Spec.**	**Sens.**	**Spec.**	**Sens.**	**Spec.**
Diag. Test vs. DPOAE	-	90%	87%	92%	89%	96%	88%	92%
Diag. Test vs. TEOAE	50%	92%	92%	88%	93%	90%	92%	89%

From the above table it can be clearly seen that almost both TEOAE and DPOAE results have 90% specificity and sensitivity with reference to diagnostic test. The sensitivity of all the tests is low for children below 3 years of age. For age group 3-15 and above 15 years, all the three tests have almost 90% specificity and sensitivity. It can be seen that TEOAE has got better sensitivity than DPOAE for all the age groups where as DPOAE has got higher specificity than TEOAE results. The sensitivity of diagnostic test vs. DPOAE for children below 3 years could not be obtained because of the statistical limitation (i.e. true positive score was not present) in representing the data.

The ultimate goal of any screening program is to identify all ears with hearing loss while passing all ears that have normal hearing. One important but difficult to obtain measure of any screening program is the accuracy with which the screening procedure detects ears with hearing loss.

The purpose of any screening program is to identify those individuals having a defined disorder as early as possible and refer for more comprehensive (diagnostic)

testing. The objective is to accurately identify and refer those individuals with the condition (sensitivity) and dismiss individuals without the condition (specificity). This will avoid referring those individuals without the disease for further testing (false positive results) and remission of those with the disease (false negative results).

The validity of a screening test that is dependent on diagnostic confirmation for every person under consideration is determined by:

Sensitivity; i.e., the ability of a test to correctly identify patients with disease (hearing loss).

Specificity; i.e., the ability of the test to correctly identify those without disease (i.e., normal hearing).

Sensitivity can be thought of as the true positive rate, and specificity is the true negative rate.

All the three procedures OAE, diagnostic audiometry and immittance showed high specificity and good sensitivity.

In the present study sensitivity and specificity is seen to be around 90%. This suggests that either DPOAE or TEOAE test can identify the individual with hearing loss 90% of the time and 90% of the subjects without hearing loss can be detected. This good sensitivity and specificity is seen mainly due to large number of ears tested in each group and also very less discrepancy in test results is obtained.

A pass in TEOAE screening does not necessarily imply a pass in DPOAE screening for the same child. The high sensitivity and specificity observed in this study has not been reported previously. Lutman, Davis, Fortnum & Wood (1997) reported the sensitivity of TEOAEs measured at birth around . 80%.

Cost Effectiveness: -

In the present study, cost effectiveness for TEOAE and DPOAE was found. The instrument used for DPOAE and TEOAE screening was the same i.e., ILO 286. Thus the cost effectiveness of each test will vary depending upon the total number of subjects screened using two methods independently. More the number of subjects screened, lesser will be the cost as rest of the factor like cost of the instruments, salary, transport etc. will remain the same. It was seen that DPOAE takes less time for normals where as it takes more time than TEOAE for hearing loss subjects. Thus, the time taken to screen depends on the type of population to be screened i.e., whether there is more number of hearing loss subjects or normal hearing subjects.

The average time taken to screen normal hearing individuals using DPOAE is about 30 seconds in subject with hearing loss it took around 2-min. 30 sec. including preparation time, where as TEOAE measurement takes approximately 45 sec. for normal hearing subjects and 1 min 30 sec including preparation time to screen hearing loss individuals. If the population to be screened has significantly more individuals with normal hearing then DPOAE measures will take less time resulting in more number of subjects screened per day. If the population to be screened has relatively equal number of individuals with normal hearing and hearing loss then

TEOAE measurement will take lesser time resulting in more number of people screened in a day thus reducing the cost.

In the present study out of 486 ears tested, 213 ears had normal hearing and 271 ears had hearing loss. Thus, DPOAE measurement took longer time than the TEOAE measurement resulting in TEOAE to be a more cost effective tool.

However, the screening is administrated in population where we can expect significantly larger group of population having normal hearing than the abnormal population. In such incidences DPOAE will be less costly tool to screen than the TEOAE.

Test time for screening is highly variable and dependent on many factors. Under ideal condition and with a normal hearing, infant, OAE screening may require less than 30 sec/ear. On the other hand, with excessive measurement noise, subject's own physiological noise (respiration), OAE screening might take long time (e.g. >30 sec/ear) as reported earlier by Doyle, Fowler and Starr (1996).

General Observation: -

Difficulties/problems encountered during screening:

Lot of physical activity was seen in younger children. Restlessness of the child and hence enhanced body movements made it difficult to measure OAE for few younger children. Most of the younger children were tested when they were in deep sleep, which helped to obtain reliable OAE measures.

SUMMARY AND CONCLUSION

Hearing screening has been attempted during the past 60 years with a variety of test methods: objective, subjective or in combination.

Over the years, many modifications and advances have been brought forth to improve the screening methods, procedure and instruments. One of the attempts of this was the development of OAE instrument.

The striking feature of OAE, which made it more popular, was faster procedure, good accuracy, lesser cost and higher sensitivity (White, Vohr & Behrens, 1993; Brass & Kemp, 1994; Aidan, Avan & Bonfils, 1999). EOAEs were made use of for the purpose of early identification of hearing impairment in neonates, not only high risk but also healthy neonates.

Hearing screening is a very important for the early detection of hearing problems. If hearing loss is left undetected it can lead to delay in speech and language development and several other problems like poor academic performance, emotional problem, behavioral problem etc. thus it is important to detect hearing problems by screening as early as possible.

The present study was taken up with the aim to assess the efficacy of:

a) TEOAE and DPOAE in hearing screening,

b) Sensitivity and specificity of each test procedure and

c) Cost effectiveness of each procedure.

A total of 484 ears in the age range of below 3 years, 3 to 15 years and above 15 years were tested using diagnostic test i.e. pure tone audiometry and immittance, and screened using TEOAE and DPOAE. Ears where pure tone threshold could not be obtained, BOA and ABR was done to find out thresholds. TEOAE and DPOAE responses were taken in terms of pass or fail based on the criteria given in the instrument. The individual who had pure tone threshold more than 15dB and abnormal Immittance results or no response at 30dBHL in ABR was considered as fail.

The results obtained from the study were statistically analyzed with the Phi-correlation coefficient. From the results obtained it was noticed that a positive correlation exists between results obtained using the diagnostic testing and both TEOAE and DPOAE screening in all most all the age groups.

High significant correlation was found between the diagnostic test Vs. TEOAE and Diagnostic test Vs. DPOAE for all age groups.

It is evident from the results that DPOAE and TEOAE have almost 90% sensitivity and specificity and take almost same time in the identification of normal hearing and hearing impaired subjects. Also DPOAE is seen to be cost effective when the population has more individuals with normal hearing where as TEOAE takes less cost if population screened has more or equal number of hearing impaired subjects.

A screening test must be selected that will most effectively pick up the conditions to be identified. A good screening tool should be acceptable, reliable, valid and cost-effective (Paradise, Smith & Bluestone, 1976).

From the above description, it could be concluded that OAE can be found in all the age groups. It is an objective and automatic procedure and is the fastest screening instrument in environment where there is low ambient noise. Smurzynski et al. (1993) reported presence of well-developed DPOAE in newborn based on screening results using DPOAEs. DPOAE promises to be an efficient screening tool having an edge over TEOAE.

Implications: -

Either TEOAE or DPOAE can be used as a screening test. Among the two DPOAE is recommended as it takes lesser time to administer when the population to be screened has more number of individuals with normal hearing. Secondly, sensitivity & specificity of DPOAE and TEOAE is very high, thus reducing the false positive or negative and number of patients for whom anxiety occur would be less.

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