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THE EFFECTS OF TYMPANIC MEMBRANE PERFORATIONS ON THE DETECTION OF DISTORTION PRODUCT OTOACOUSTIC EMISSIONS

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ABSTRACT

Objectives: To investigate the effects of human's tympanic membrane perforations on distortion product otoacoustic emissions. **Patients and Methods:** 42 patients who had tympanic membrane perforations aged between 16 and 60 years of both genders were included in the study which carried out at King Hussein Medical centre (Jordan) between 4th of august 2015 and 10th of May 2021. Otoscopic examination performed by ENT doctors, followed by pure tone audiometery using clinical diagnostic audiometer and distortion product otoacoustic emissions using Escort system were carried out on each ear of the subjects by a qualified audiologist and in an isolated booth. **Results:** Distortion product Otoacoustic emissions (DPOAEs) in ears with small perforation size less than 25% were significantly lower than those in the intact membranes at low frequencies P <0.05 but not significantly lower at high frequencies. Perforation size of 40-50% severely affected DPOAEs results; they were significantly lower than those in the intact membranes P< 0.05. Perforation size more than 70% severely affected DPOAEs results that the emissions did not differ from the noise floors P < 0.05. **Conclusion:** presence of small tympanic membrane perforations doesn't preclude the detection of distortion product otoacoustic emissions. However, large perforations affected the detection of emissions in the low frequencies region.

KEYWORDS: Distortion product otoacoustic emissions, Tympanic membrane perforation, pure tone audiometery, conductive hearing loss, hearing threshold.

INTRODUCTION

Otoacoustic emissions (OAEs) are sounds produced by the outer hair cells of cochlea that can be recorded in the outer ear canal.[1] Two types of emissions, transient evoked otoacoustic emissions (TEOEs) and distortion product otoacoustic emissions (DPOEs) are considered to have clinical utility to provide a measure of cochlear function.[2-6] To date TEOEs have received more clinical attention than DPOEs, which are the focus of the current study.[2]

Otoacoustic emissions are the results of an active process in the organ of Corti,[7] and they can be used as a useful, objective and noninvasive screening tool to determine the presence or absence of cochlear function.[8] The ability to detect otoacoustic emissions is dependent on the viability of the conduction apparatus of the ears.[9] Therefore the reliability of measurements of otoacoustic emission in cases of middle ear conductive disorders, such as tympanic membrane perforations, otitis media with effusion, and otosclerosis requires further study.[10]

In the mammalian ear, distortion product otoacoustic emissions (DPOEs) result from the interactions of two pure-tones with frequencies f1 and f2, with f2 >f1. The most prominent DPOE occurs at 2f1-f2.[11] Interest in the clinical applications of DPOEs is increasing because they are rapidly obtained and provide objective, frequency-specific information about cochlear function.[8]

Concerning the effects of tympanic membrane perforations on distortion product otoacoustic emissions, there was a study reported in the literature which was carried out by Wadsworth et al[10] using the guinea pig as controlled model, they made perforations of various sizes to determine how much perforation would still allow for the detection of DPOAEs. They concluded that small perforations, up to 25% of the area of the tympanic membrane, still allow us to detect emissions at the specified frequencies. However, perforations of 50% and larger, as well as those accompanied by traumatic perilymph fistulas and ossicular disarticulations, severely interfered with the detection of DPOAEs.

The present study was set out in order to test the hypothesis whether human ear's tympanic membrane perforations could still allow the detection of distortion product otoacoustic emissions (DPOAEs).

PATIENTS AND METHODS

A total number of 42 patients who had tympanic membrane perforations aged between 16 and 60 years of both genders who presented to otolaryngology department at King Hussein Medical centre (Jordan) between 4th of August 2015 and 10th of May 2021 were studied prospectively.

All patients underwent an otoscopic examination by ENT doctors, then the patients underwent pure tone audiometery to determine the hearing threshold levels for each ear of the patients using clinical diagnostic audiometer, after that tympanometery testing was carried out on the normal ear of each patient to test the function of middle ear, and finally distortion product otoacoustic emissions measurements were carried out on each ear of the participants using diagnostic protocol (750-8000 Hz) through an escort system. All measurements were carried out in an isolated test booth at the audiology unit of King Hussein Medical centre by a qualified audiologist.

All measurements were measured twice to ensure the reliability of the findings.

RESULTS

Table (1) shows the result of pure tone audiometer which carried out on the both ears of the 42 patients who participated in the study; unilateral normal hearing were found in 22 ears, unilateral conductive hearing loss (CHL) found in 22 ears, and bilateral CHL found in 10 ears, bilateral SNHL found in 2 ears, bilateral mixed hearing loss found in 4 ears and bilateral profound hearing loss found in 4 ears.

Those patients who demonstrated bilateral conductive hearing loss, bilateral sensory neural hearing loss, bilateral mixed hearing loss and bilateral profound hearing loss were excluded from the analysis, because it was difficult to establish base line readings for making a comparison.

The analysis of the results were only limited to the 22 ears of unilateral CHL due to perforated tympanic membrane without discharge, and the control group used in the study was the normal ear of each subject, therefore, the control group consists of 22 normal ears who demonstrate normal hearing threshold level < 20 dB HL, normal tympanometery, and strongly detected otoacoustic emissions.

Of these 22 perforated tympanic membranes, variable degrees were found and different sizes of tympanic membrane perforations were revealed by otoscopic examination. Therefore to make the comparison of the analysis easier we classified the degrees of hearing losses according to the size of tympanic membrane perforations as shown in table (2) and figures (1.2.3).

Table (2) shows the groups of conductive hearing loss (CHL) according to the degrees and the sizes of the perforations:

Group (1) consists of 8 ears that showed mild conductive hearing loss (CHL) at low frequencies with perforation size less than 25 %.

Group (2) consists of 8 ears that showed mild to moderate conductive hearing loss (CHL) with perforation size of 40-50 %.

Group (3) consists of 6 ears that showed moderate conductive hearing loss (CHL) with perforation size more than 50 %.

Figure (1) shows the mean hearing threshold levels of 8 ears with mild conductive hearing loss (CHL) and a small perforation less than 25 % , it is apparent that the loss were in the low frequency region and the degree of loss were in the range of 40 dB.

Figure (2) shows the mean hearing threshold levels of 8 ears with mild to moderate conductive hearing loss (CHL) and perforation size of 40-50%.it is apparent that the loss were in the low frequency region and the degree of loss were in the range of 60 dB due to the effect of perforation size.

Figure (3) shows the mean hearing threshold levels of 6 ears with moderate CHL at all tested frequencies with perforation size more than 50 %. it is apparent the loss were at all tested frequencies in the range of 60 dB as the size of perforation increased resulted in more conductive hearing loss.

Table (3) shows the mean DPOAEs of group one of 8 ears with mild conductive hearing loss and a small perforation size < than 25 %, It is apparent that DPOAEs in this group did not differ significantly from DPOAEs in the control group at high frequencies, but it differ significantly at low frequencies even it can be detected at lower levels. $P \leq 0.05$

Table (4) shows the mean DPOAEs of group two of 8 ears with moderate to mild conductive hearing loss and perforation size of 40-50 %, It is apparent that DPOAEs in this group were detectable at low frequencies, as well as at the high frequencies but the amplitudes were lower than those in the normal ear.

Table (5) shows the mean DPOAEs of group three of 6 ears with moderate conductive hearing loss at all tested frequencies and perforation size more than 50 %, it is apparent that DPOAEs amplitudes in this group were lower than those in the normal ears. Significantly differs from the control group as the noise floor contaminated the DPOAEs findings. $P \leq 0.05$

DPOAEs in group 1 with mild CHL at low frequencies significantly lower at $p \leq 0.05$ than those in group 3 with CHL at all tested frequencies.

Table (6) shows the DPOAEs amplitudes of 22 ears who considered as a control group; it is apparent the amplitudes are higher than those obtained from the subject groups.

Regarding to pure tone audiometery, there was a significant difference between the mean threshold levels of mild CHL at low frequencies and CHL at all tested frequencies. $p \leq 0.05$

Statistical analysis

t- Test of unequal variance was used to calculate the significant differences ($P \leq 0.05$). The comparisons were among the mean DPOAEs of 4 groups as shown in table 7.

DISCUSSION

Otoacoustic emissions have been the subject of considerable interest[7,8,12] since they were first reported by Kemp in 1979.[13]

The effects of myringotomy and tympanostomy tubes on evoked otoacoustic emissions have been previously reported.[9,14]

In the study by Owens et al[9] ears with ventilation tubes had exhibited OAE amplitudes smaller than those from healthy ears, but larger than those of the untreated diseased ears. Moreover at 6 weeks following the procedure OAE levels for the both TEOAEs and the DPOAEs were improved to normal or near normal amplitude. Thus OAEs can also be used as a means to monitoring the efficacy of medical or surgical intervention on the transmission properties of the middle ear in conditions involving otitis media.

Although the presence of ventilation tubes does not result in a total loss of previously measurable TEOAEs in ears with emissions present prior to myringotomy and ventilation tube insertion, the presence of ventilation tubes appears to modify the properties of the TEOAEs, resulting in lower amplitudes in the mid to high frequencies <4 kHz [14]. Based on these results a ventilation tube may be expected to function in a similar manner as a small dry perforation of the tympanic membrane and allow for measurable OAEs.

The detection of distortion product otoacoustic emissions depends on many factors intrinsic to the auditory pathway. To generate DPOAEs, it is required to have a functional cochlea with normal outer hair cells. However, detection of distortion product otoacoustic emissions is not independent on the ears conduction apparatus. Because DPOAEs generated in the cochlea are conducted through the middle ear; their measurement can be altered by middle ear dysfunction.

The forward acoustic stimulus used to evoke an emission can also undergo changes due to impaired middle ear transduction. It's likely both factors play a role in altering distortion product otoacoustic emissions measurements.

The results of the current study show that perforation of tympanic membrane doesn't necessarily interfere with the detection of distortion product otoacoustic emissions in human beings.

The size of the Perforation had a direct relationship to DPOAEs amplitude, as amplitude become lower when the perforation becomes larger. DPOAEs can be detected in the presence of perforation as large as 25% at the specified tested frequencies, even so perforation size of about 40-50% still allow DPOAEs to be detected at high frequencies , but the amplitude are significantly lower than in normal ears.

The results of our study are consistent with results obtained by Wadsworth 2000, on guinea pig model.

Table 1: Types of hearing loss in 42 patients.

Type of hearing loss	Unilateral	Bilateral
Within Normal	22	--
Conductive hearing loss (CHL)	22	10
Sensory neural hearing loss (SNHL)	--	2
Mixed hearing loss	--	4
Profound hearing loss	--	4

Table 2: Degree of conductive hearing loss and size of tympanic membrane perforation of 22 ears.

Degree of hearing loss	Size of tympanic membrane perforation as revealed by otoscope	Number of Ears
Group 1 with mild CHL	< 25 %	8
Group 2 with moderate to mild CHL	40-50 %	8
Group 3 with moderate CHL	> 50 %	6

Table 3: Mean dpoaes amplitude of group one.

Frequency (Hz)	DP (dB)	NF (dB)	DP-NF (dB)
7280	-3.5	-18.2	14.7
5133	-8.6	-18.2	9
3640	-12.2	-20.2	8
2566	-12.6	-20.9	8.3
1797	-18.3	-22.1	3.8
1283	-18.9	-22.9	4
932	-2.2	-9.1	6.9
676	-2	-1.9	-0.1

Table 4: Mean dpoaes amplitude of group two.

Frequency	DP (dB)	NF (dB)	DP-NF (dB)
7280	-6.6	-16.2	9.6
5133	-10.2	-16.4	6.2
3640	-16.4	-20.2	3.8
2566	-10.6	-12.2	1.6
1797	-18.6	-19.7	1.1
1283	-20.2	-19.2	-1
932	-20.2	-20	-0.2
676	-22.2	-18.2	-4

Table 5: Mean dpoaes amplitude of group three.

Frequency	DP (dB)	NF (dB)	DP-NF (dB)
7280	-12.2	-14.4	2.2
5133	-10.2	-12.2	2
3640	-12.2	-10.1	-2.1
2566	-10.8	-10.6	-0.2
1797	-18.2	-16.2	-2
1283	-20.6	-16.8	-3.8
932	-22.8	-18.2	-4.6
676	-20.8	-18.2	-2.6

Table 6: Mean dpoaes amplitude of control group.

Frequency(Hz)	DP(dB)	NF(dB)	DP-NF
7280	10.4	-2.6	13
5133	16.8	-1.8	18.6
3640	10.2	1.9	8.3
2566	8.3	1.9	4.6
1797	5.6	-3.4	9
1283	-10.5	-23.5	13
932	-8.6	-1.6	4
676	-8.8	-20.6	11.8

Table 7: The mean dpoaes amplitudes of the four groups.

Group/ DP	Frequency (Hz)							
	7280	5133	3640	2566	1797	1283	932	676
Group 1	14.7	9.4	8	8.3	3.8	4	6.9	0.1
Group 2	9.6	6.2	3.8	1.6	1.1	-1	-0.2	-4
Group 3	2.2	2	-2.1	-0.2	-2	-3.8	-4.6	-2.6
Control	13	18.6	8.3	4.6	9	13	4	11.8

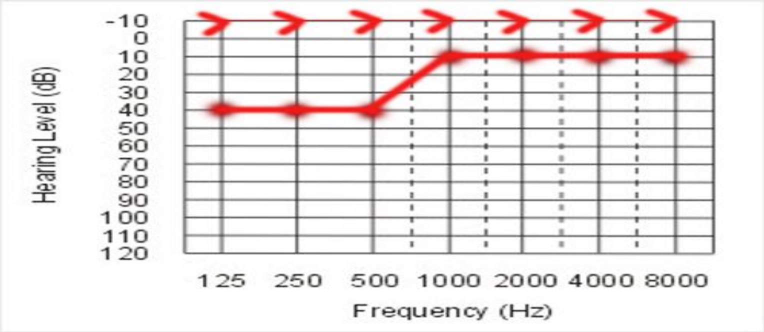

Figure 1: The Mean Hearing Threshold Levels of Group One with Mild CHL and a Small Perforation Less than 25 %.

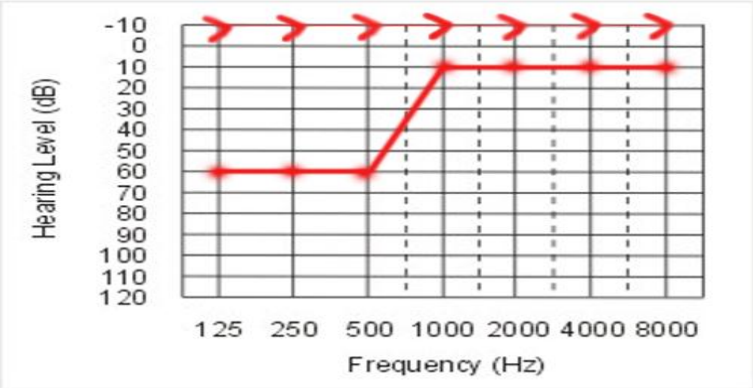

Figure 2: The Mean Hearing Threshold Levels of Group Two with Moderate to Mild CHL and Perforation size of 40-50 %.

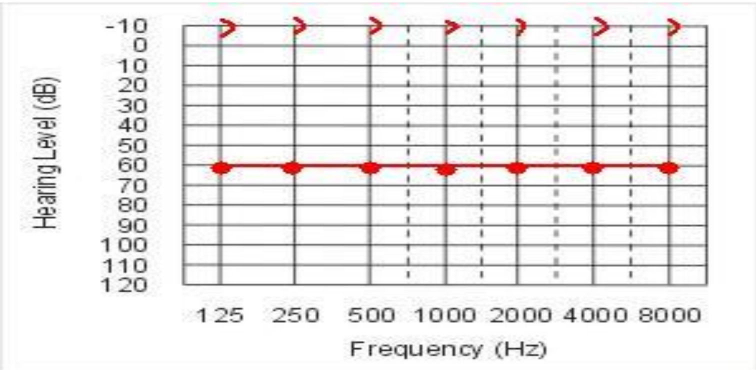

Figure 3: The Mean Hearing Threshold Levels of Group Three with Moderate CHL and Perforation size > 50 %.

CONCLUSION

Presence of small tympanic membrane perforation doesn't preclude the detection of distortion product otoacoustic emissions. However, large perforation did preclude the detection of otoacoustic emissions in low frequencies region.

Conflict of interest

The authors declare no competing interest.

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