AIM OF THE WORK

The aim of the work is to study the effect of contralateral noise presentation on the thresholds of ASSR for 40-Hz and 80-Hz AM tones in patients diagnosed with ANSD.

PATIENTS

This study was carried on 10 adult patients (20 ears) with ANSD attending the audiology clinic at Alexandria University Main Hospital starting from the date of proposal endorsement for one year (December 2013).

An informed consent was taken from every subject with full ENT history and otological examination.

Selection criteria:

All the patients fulfilled the criteria needed to diagnose AN as follows:

1. Hearing loss up to moderate degree and any configuration shown by PTA with speech discrimination out of proportion to the amount of hearing loss.
2. Absent ABR for 90 dBHL clicks despite satisfactory audiometric thresholds at high frequencies.
3. Intact Transient Evoked Oto-Acoustic Emission (TEOAEs).
4. Patients with ANSD that proved to show ASSR thresholds in a study that was done in Audiology Unit, Alexandria University. [142]

METHODS

All subjects in the study were subjected to the following procedure:

I- Clinical examination:

1. Detailed history taking including general medical history, history of ear diseases and previous ear operations.
2. Otologic examination to exclude external or middle ear pathology.

II- Basic audiological evaluation:

1. Pure tone audiometry:

Pure tone audiograms were obtained for each ear of all subjects using a double channel clinical audiometer (Interacoustics AC33). Pure tone thresholds were typically obtained under supraural TDH-49 headphones at 250, 500, 1000, 2000, 4000 and 8000 Hz. The maximum intensity for stimulation was 110 dB HL. Pure tone threshold levels were determined using a 10 dB down and 5 dB up search technique in each stimulation frequency. Bone conduction thresholds were obtained to exclude conductive hearing loss. All pure tone threshold tests were conducted in a sound-treated booth.

2. Speech audiometry:

Speech reception thresholds (SRT) and speech discrimination scores (SDS) were obtained using a double channel clinical audiometer (Interacoustics AC33) using Arabic bisyllabic and monosyllabic phonetically balanced words, respectively.

3. Acoustic immitance measures:

Tympanometry and acoustic reflexes were performed using a tympanometer model "Amplaid AZ7".

III- Otoacoustic emissions:

(TEOAEs) were measured using ILO-96 otodynamic analyzer-version 5. TEOAEs were elicited using click stimuli at stimulus intensity ranges from 85 dB SPL – 90 dB SPL. TEOAEs were analyzed during 20 ms after stimulus presentation by non-filtered clicks of 80 µs at a rate of 50/s. In one session recording 260 response were averaged within five bands (1, 1.5,2,3 and 4 kHz). The amplitude of TEOAEs was automatically determined.

#: These data were collected from previous study utilizing the same patients. [142]

IV- Electrophysiological evaluation:

1. Auditory brainstem response (Click-ABR)[#]:

ABR was performed using Evoked response audiometer model smart EP intelligent hearing systems version 1.0. ABR measures were obtained in a quiet room and all subjects were tested in total relaxation and a comfortable state.

Electrode montage:

One channel recordings were obtained using ipsilateral electrode montage. Active electrode was placed on the high forehead (Fz), while the reference electrode was placed on the mastoid of the stimulated ear and the ground electrode on the contralateral mastoid. Disposable electrodes were used. Electrode sites were cleaned with alcohol and rubbed with rough gauze to lower skin resistance. To ensure balanced inputs to the differential amplifier and optimize signal to noise ratio, electrode impedance did not exceed 3000 Ohms and differences between electrode pairs were kept below 2000 Ohms.

Stimulus parameters:

Click stimuli were generated by D.C pulse via a TDH-49 ear phone. Rarefaction clicks were used and presented at a stimulation rate 19.4 stimuli/sec with a 12 msec epoch.

Each averaged response was based upon 1024 stimulus repetitions and was replicated once to permit assessment of response reproducibility. Monaural stimulation was employed with a stimulus presentation level of 90 dB.

Recording parameters:

Click ABR was recorded using filter settings between 100 to 3000 Hz (6 dB/ octave) and amplified using a gain of 100,000. Artifact rejection of 31 μV was used to minimize contamination of the ABR by myogenic activity. The time window was taken as 12.5 milliseconds. At each presentation level, a minimum of 1024 sweeps were averaged and was replicated at least once.

2. Auditory Steady State Response (ASSR):

Single channel monotic ASSR was carried out using the GSI AUDERA evoked potential system. All subjects were tested in a quiet room and were resting comfortably and were in total relaxation state.

Electrode montage:

EEG activity was measured using disposable electrodes. Differential recordings were made with the high forehead, the ipsilateral mastoid and a ground electrode placed on the contralateral mastoid. Electrode impedance was minimized using alcohol and rough gauze and was typically no more than 5000 Ohms.

#: These data were collected from previous study utilizing the same patients. [142]

Stimulus parameters:

The stimulus tones were presented via GSI TIP50 insert earphones with foam earplugs. The test stimuli were 500 and 4000 Hz amplitude and frequency modulated tones individually presented. The test signals were modulated at rates of 74and 95 Hz respectively. 100% Amplitude modulation and 10% frequency modulation were combined to maximize response amplitude (enhanced at the carrier frequencies).

Threshold search for both 40-Hz and 80-Hz ASSR was done in 10 dB down- 5 dB up procedure.

Contralateral noise:

Contralateral sound level was 70 dBHL of broad band noise. The effect of this sound presented to the contralateral ear was examined on the threshold measurements of ASSR for 40-Hz and 80-Hz AM tones. First, thresholds of the 40-Hz and 80-Hz ASSR at 500 and 4000 Hz MM tones were measured without contralateral noise. Then, thresholds of the two potentials were re-measured at the same CFs with contralateral noise for both potentials at each ear.

Suppression magnitude was assessed as threshold elevation (average 10 to 15 dB) of both potentials with presentation of contralateral noise.

Recording parameters:

ASSR analysis was carried out in the manner described by Cohen et al. (1991) in which, the raw EEG was passed through a preamplifier, band pass filtered (10 Hz to 500 Hz), and then Fourier analyzed at the stimulus modulation frequency to extract response phase and amplitude information. The presence or absence of a response was then determined automatically with a statistical detection criterion based on phase coherence.

The system calculated the probability that a set of observed phase angles could occur in the absence of a response. If this probability was sufficiently small ($p < 0.03$), a response was considered to be present ($p < 0.03$ is the default criterion for the GSI AUDERA evoked potential system).

The AUDERA system has three result options: "**phase locked**" indicating that an ASSR has been identified, "**random**" where no response could be detected under good recording conditions (fig: 5) and "**noise**" where the detection algorithm detects EEG and/or myogenic noise that exceed a predetermined level. "Noise" results are not included in the threshold-determination process. Threshold was defined as the lowest level at which a statistically significant response could be obtained (phase locked) and for which the next-lowest presentation level showed no response (random).

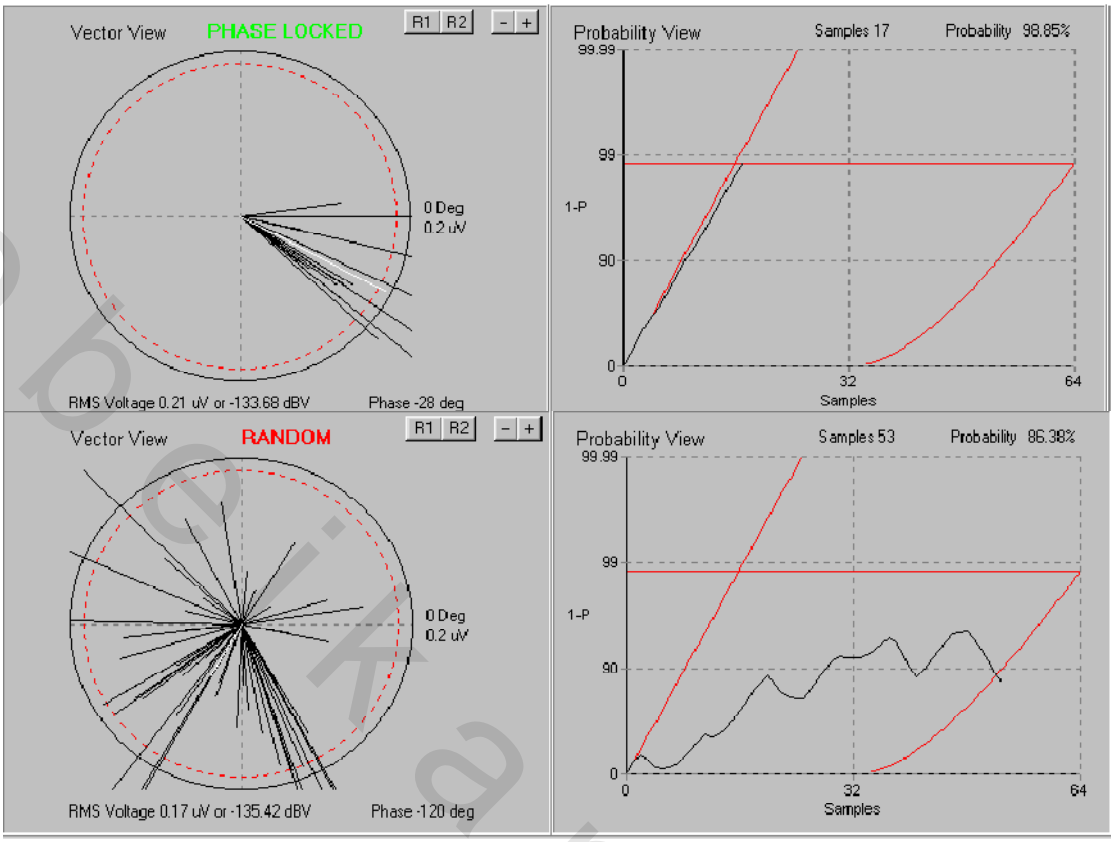

Figure (5): A picture of 2 result options of GSI AUDERA in the form of phase locked and random.

RESULTS

A total number of ten adult participants (20 ears) with ANSD, ranging in age from 15 to 53 years, shared in the study. According to the degree of hearing loss, ten ears had mild degree of SNHL and ten ears had moderate degree of SNHL. Two frequencies (500 and 4000 Hz) were evaluated before and after suppression by contralateral noise, at the two ASSR potentials; 40 and 80 Hz.

I. Descriptive distribution of participants:

The sex, age, degree of hearing loss and overall OAEs reproducibility of the participants are presented in table (1).

Table (1): Distribution of studied sample regarding the demographic data and audiometric profile.

	No.	%
Sex (n = 10)		
Male	6	60.0
Female	4	40.0
Age (n = 10)		
Min. – Max.	15.0 – 53.0	
Mean ± SD.	26.0 ± 11.10	
Degree of hearing loss (n = 20 ears)		
Mild	10	50.0
Moderate	10	50.0
Otoacoustic emissions reproducibility in percentage (n = 20 ears) *		
Min. – Max.	78.0 – 99.0	
Mean ± SD.	91.25 ± 6.65	

*: Data were taken from previous measurements utilizing the same patients [142]

II. Pure tone thresholds assessment:

The descriptive statistics of pure tone thresholds in dB HL of the studied sample at the frequencies of 250, 500, 1000, 2000, 4000 and 8000 Hz; are presented in table (2) and figure (6). Figure (6) shows the mean and standard deviation (SD) of pure-tone thresholds in dB HL for the studied sample across the six tested frequencies.

Table (2): Distribution of studied sample of Pure tone audiometry thresholds (n = 20 ears)

	Min. – Max.	**Mean ± SD**
Frequencies		
250	30.0 – 80.0	48.50 ± 13.68
500	30.0 – 65.0	49.0 ± 10.59
1000	20.0 – 60.0	38.50 ± 9.75
2000	20.0 – 45.0	28.0 ± 8.34
4000	20.0 – 50.0	29.50 ± 9.30
8000	20.0 – 75.0	32.50 ± 15.35

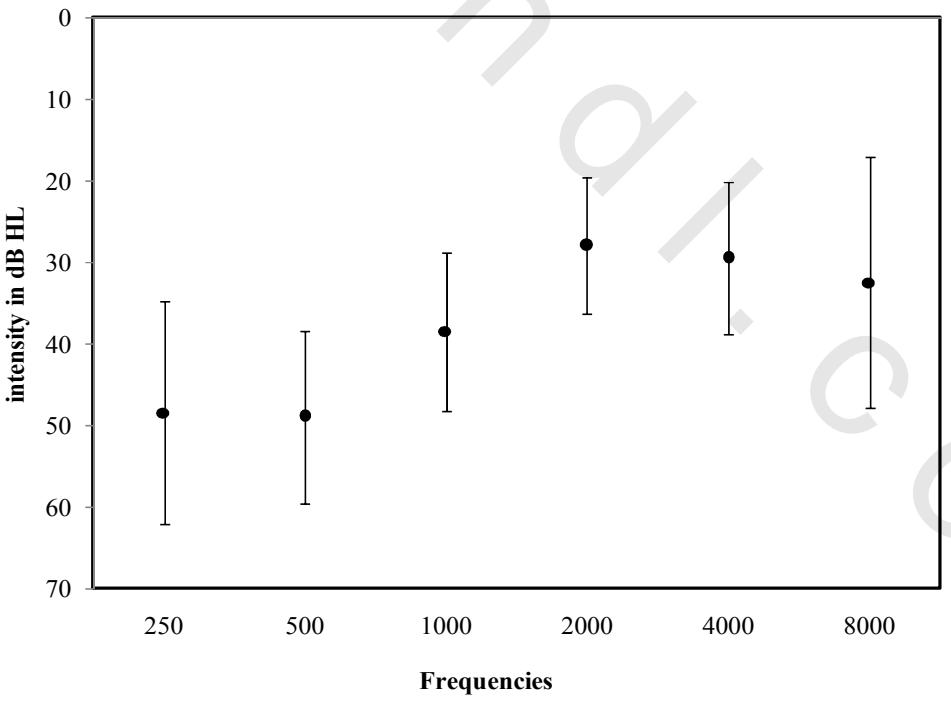

Figure (6): Distribution of the studied sample of Pure tone audiometry thresholds in dB HL.

III. Analysis per patient:

The amount of suppression was considered as the difference between thresholds of ASSR before and after contralateral noise that measured of 40 Hz and 80 Hz ASSR thresholds at 500 and 4000 Hz. This amount of suppression measured in Right ear and Left ear, were analyzed. Table (3) and figures (7,8) show correlation between Right ear and left ear.

Table (3): Correlation between Right and Left ear regarding amount of suppression.

		Right	Left	r_s (p)	Z (p)
40 Hz ASSR	**500 Hz**	**(n = 8)** #	**(n = 8)**	0.207 (0.623)	1.342 (0.180)
	Min. – Max.	0.0 – 10.0	0.0 – 5.0		
	Mean ± SD	3.13 ± 3.72	1.25 ± 2.31		
	Median	2.50	0.0		
	4000 Hz	**(n = 10)**	**(n = 10)**	0.232 (0.519)	1.190 (0.234)
	Min. – Max.	0.0 – 15.0	0.0 – 10.0		
	Mean ± SD	5.0 ± 5.27	3.0 ± 3.50		
	Median	5.0	2.50		
80 Hz ASSR	**500 Hz**	**(n = 5)** ##	**(n = 5)**	0.408 (0.495)	0.577 (0.564)
	Min. – Max.	0.0 – 5.0	0.0 – 5.0		
	Mean ± SD	1.0 ± 2.24	2.0 ± 2.74		
	Median	0.0	0.0		
	4000 Hz	**(n = 8)** ###	**(n = 8)**	0.586 (0.127)	0.577 (0.564)
	Min. – Max.	0.0 – 10.0	0.0 – 5.0		
	Mean ± SD	2.50 ± 3.78	3.13 ± 2.59		
	Median	0.0	5.0		

Z: Z for Wilcoxon signed ranks test
r_s: Spearman coefficient
*: Statistically significant at $p \leq 0.05$
#: 2 subjects had unilateral response, were excluded from analysis
##: 4 subjects had no response and 1 subject had unilateral response, were excluded from analysis.
###: 2 subjects had unilateral response, were excluded from analysis

Spearman correlation coefficient (r) was calculated between Right ear and Left ear regarding the amount of suppression measured in 500 Hz and 4000 Hz at both potentials. The subjects that had unilateral response or no response at any frequency in either potential were excluded from analysis. The results show no significant correlation ($p \leq 0.05$) between amount of suppression in Right ear and Left ear at any tested frequency at both potentials.

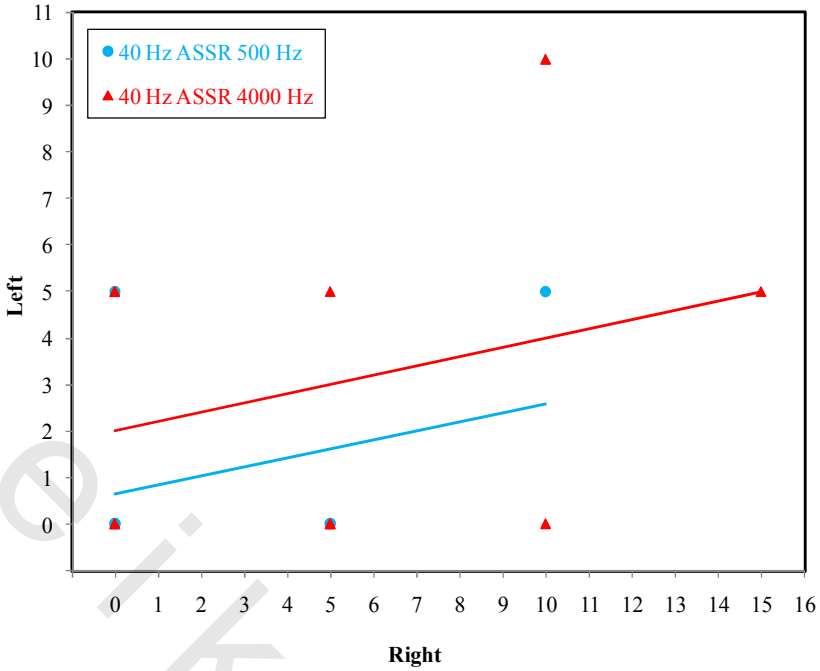

Figure (7): Correlation between amount of suppression of 40 Hz ASSR thresholds at 500 Hz and 4000 Hz frequencies in Right and Left ear.

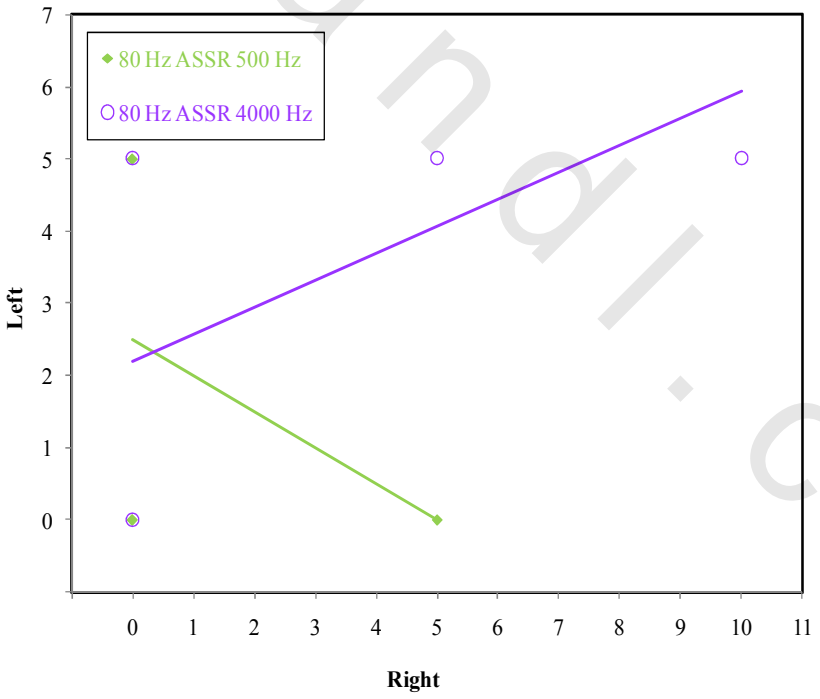

Figure (8): Correlation between amount of suppression of 80 Hz ASSR thresholds at 500 Hz and 4000 Hz frequencies in Right and Left ear.

Figure (7,8) show scatter plot of amount of suppression of 40 Hz and 80 Hz ASSR at 500 and 4000 Hz frequencies in right and left ear in the studied sample where x axis is the right ear and Y axis is the left ear. There is no significant correlation between amounts of suppression in Right ear and Left ear.

IV. Analysis per degree of hearing loss:

The amount of suppression that measured at the two potentials in subjects with mild and moderate degree of hearing loss, were compared. The sample was 5 subjects with bilateral mild degree of hearing loss (10 ears) and 5 subjects with bilateral moderate degree of hearing loss (10 ears). Table (4) and figures (9-12) show difference between mild and moderate degrees of hearing loss.

Table (4): Comparison between mild and moderate degree of hearing loss regarding amount of suppression

		Mild	Moderate	Z	p
40 Hz ASSR	**500 Hz**	**(n = 10)**	**(n = 8)** #		
	Min. – Max.	0.0 – 10.0	0.0 – 5.0		
	Mean ± SD	3.13 ± 3.72	2.0 ± 2.58	0.607	0.544
	Median	2.50	0.0		
	4000 Hz	**(n = 10)**	**(n = 10)**		
	Min. – Max.	0.0 – 15.0	0.0 – 10.0		
	Mean ± SD	5.0 ± 5.27	3.0 ± 3.50	0.813	0.416
	Median	5.0	2.50		
80 Hz ASSR	**500 Hz**	**(n = 6)** ##	**(n = 5)** ###		
	Min. – Max.	0.0 – 5.0	0.0 – 5.0		
	Mean ± SD	1.67 ± 2.58	2.0 ± 2.74	0.218	0.827
	Median	0.0	0.0		
	4000 Hz	**(n = 10)**	**(n = 8)** ####		
	Min. – Max.	0.0 – 10.0	0.0 – 5.0		
	Mean ± SD	3.0 ± 3.50	3.13 ± 2.59	0.250	0.803
	Median	2.50	5.0		

Z: Z for Mann Whitney test
*: Statistically significant at $p \leq 0.05$
#: 2 ears had no response, were excluded from analysis.
4 ears had no response, were excluded from analysis.
###: 5 ears had no response, were excluded from analysis.
####: 2 ears had no response, were excluded from analysis.

Mann Whitney test was calculated between mild and moderate degrees of hearing loss regarding the amount of suppression measured in 500 Hz and 4000 Hz at both potentials. The subjects that had no response at any frequency in either potential were excluded from analysis. There were no statistically significant difference ($p \leq 0.05$) between mild and moderate degree of hearing loss regarding the amount of suppression of 40 Hz and 80 Hz ASSR thresholds at 500 and 4000 Hz frequencies. The results are shown in figures (9-12).

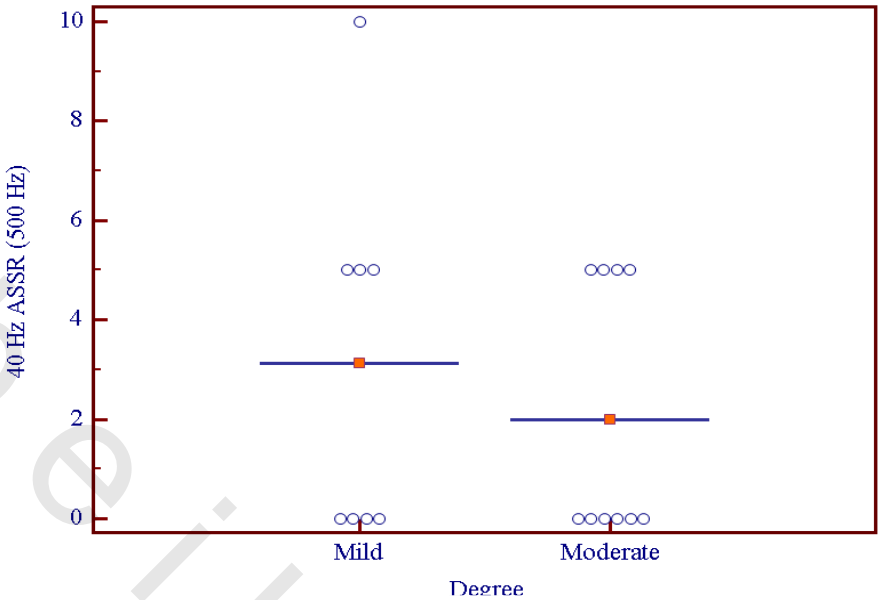

Figure (9): Scatter plot showing amount of suppression in subjects with mild and moderate degree of hearing loss in 500 Hz at 40 Hz ASSR.

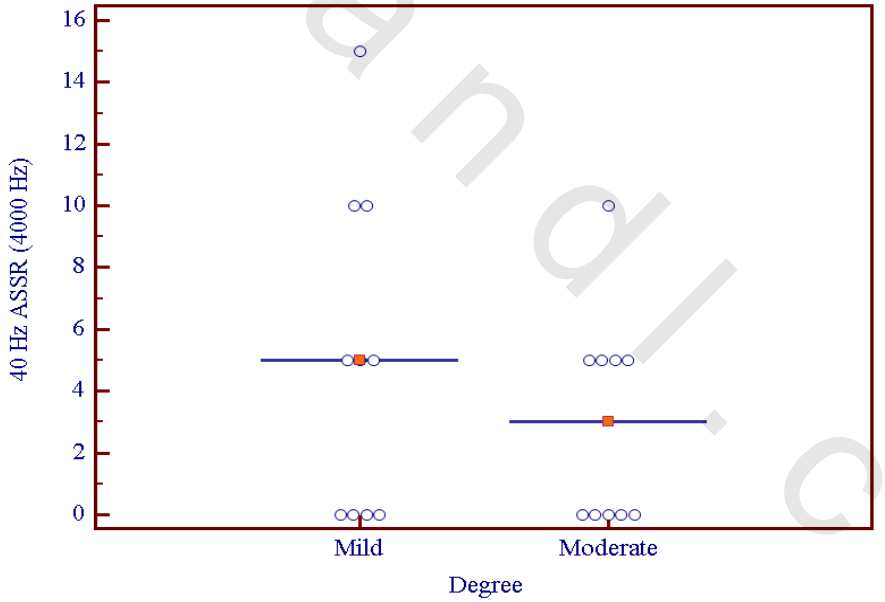

Figure (10): Scatter plot showing amount of suppression in subjects with mild and moderate degree of hearing loss in 4000 Hz at 40 Hz ASSR.

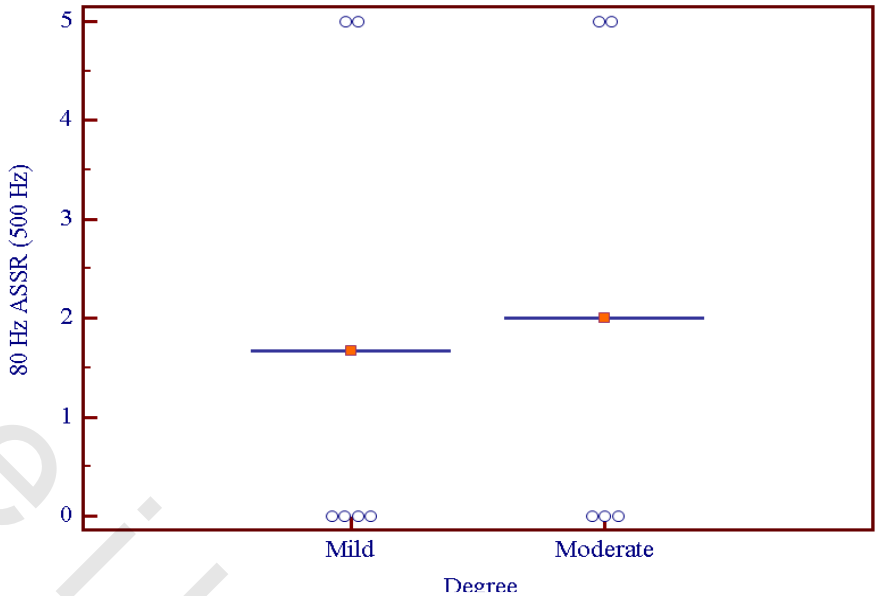

Figure (11): Scatter plot showing amount of suppression in subjects with mild and moderate degree of hearing loss in 500 Hz at 80 Hz ASSR.

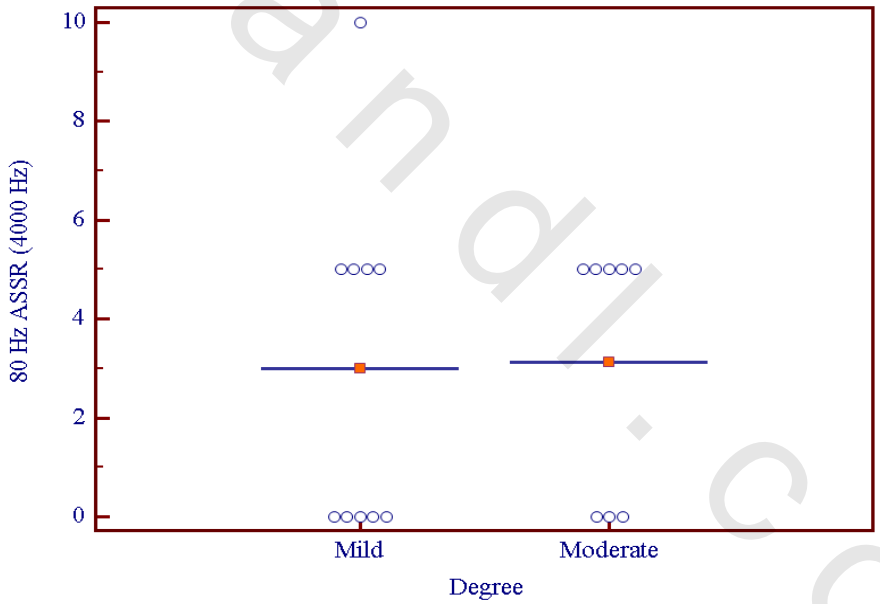

Figure (12): Scatter plot showing amount of suppression in subjects with mild and moderate degree of hearing loss in 4000 Hz at 80 Hz ASSR

Table (4) show no significant difference between mild and moderate degree of hearing loss regarding amount of suppression. Based on the previous results showed in tables (3,4) and figures (7-12), it could be concluded that the interaction between the mechanism of contra lateral suppression of both ears in the form of interference of the MOCS in the brainstem has no impact on the suppression process. Also, the degree of hearing loss (up to the moderate degree) has no effect on the amount of suppression.

In spite of the interaction between the process of suppression in both ears anatomically in every patient, each ear with its own hearing thresholds, show the suppression separately. So, it was decided to study the effect of contra lateral masking noise in each ear independently. The effect of contralateral suppression was assessed in 20 ears.

V. Effect of contralateral noise:

Comparison between ASSR hearing thresholds before and after suppression of 500 and 4000 Hz frequencies, at 40 Hz and 80 Hz ASSR potentials were presented in tables (5-8) and figures (13,14). The ears that had no ASSR response at any tested frequency were excluded from the calculation.

Table (5): Comparison between ASSR thresholds before and after suppression of 40-Hz ASSR at 500 Hz (n = 18 ears) #

40 Hz ASSR	Before suppression	After suppression	t	P
500 Hz				
Min. – Max.	75.0 – 105.0	80.0 – 110.0	3.431*	0.003*
Mean ± SD.	89.44 ± 10.13	91.94 ± 11.26		

t: Paired t-test
*: Statistically significant at $p \leq 0.05$
#: 2 ears had no responses at maximum stimulation and were excluded during calculation

Table (5) shows significant suppression of 40 Hz ASSR thresholds (P= 0.003) at 500 Hz, after introducing contralateral noise.

Table (6): Comparison between ASSR thresholds before and after suppression of 40- Hz ASSR (4000 Hz) (n =18 ears) #

40 Hz ASSR	Before suppression	After suppression	t	P
4000 Hz				
Min. – Max.	90.0 – 120.0	95.0 – 125.0	4.675*	<0.001*
Mean ± SD.	104.17 ± 10.33	109.17 ± 10.74		

t: Paired t-test
*: Statistically significant at $p \leq 0.05$
#: 2 ears had no responses on maximum stimulation and were excluded during calculation

Table (6) shows significant suppression of 40 Hz ASSR thresholds (P<0.001) at 4000 Hz, after introducing contralateral noise.

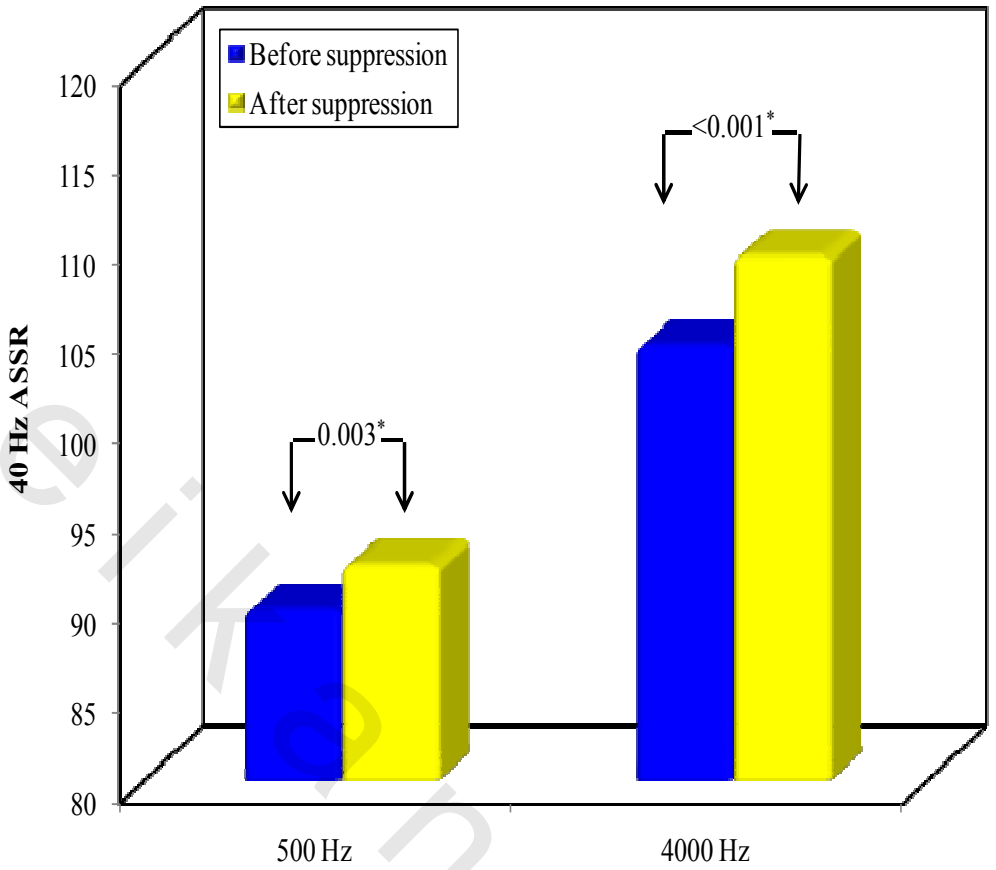

Figure (13): Comparison between ASSR thresholds before and after suppression of 40 Hz ASSR at 500 and 4000 Hz frequencies.

Table (7): Comparison between ASSR threshold before and after suppression of 80 Hz ASSR at 500 Hz (n = 11 ears) #

80 Hz ASSR	Before suppression	After suppression	t	P
500 Hz				
Min. – Max.	85.0 – 105.0	85.0 – 105.0	2.887*	0.016*
Mean ± SD.	93.18 ± 5.60	95.45 ± 6.11		

t: Paired t-test
*: Statistically significant at $p \leq 0.05$
#: 9 ears had no responses on maximum stimulation and were excluded during calculation

Table (7) shows significant suppression of 80 Hz ASSR thresholds (P=0.016) at 500 Hz, after introducing contralateral noise.

Table (8): Comparison between ASSR thresholds before and after suppression of 80 Hz ASSR at 4000 Hz (n = 18 ears) #

80 Hz ASSR	Before suppression	After suppression	t	P
4000 Hz				
Min. – Max.	110.0 – 125.0	110.0 – 125.0	4.267*	0.001*
Mean ± SD.	118.33 ± 4.54	121.39 ± 4.47		

t: Paired t-test
*: Statistically significant at $p \leq 0.05$
#: 2 ears had no responses on maximum stimulation and were excluded during calculation

Table (8) shows significant suppression of 80 Hz ASSR thresholds (P= 0.001) at 4000 Hz, after introducing contralateral noise.

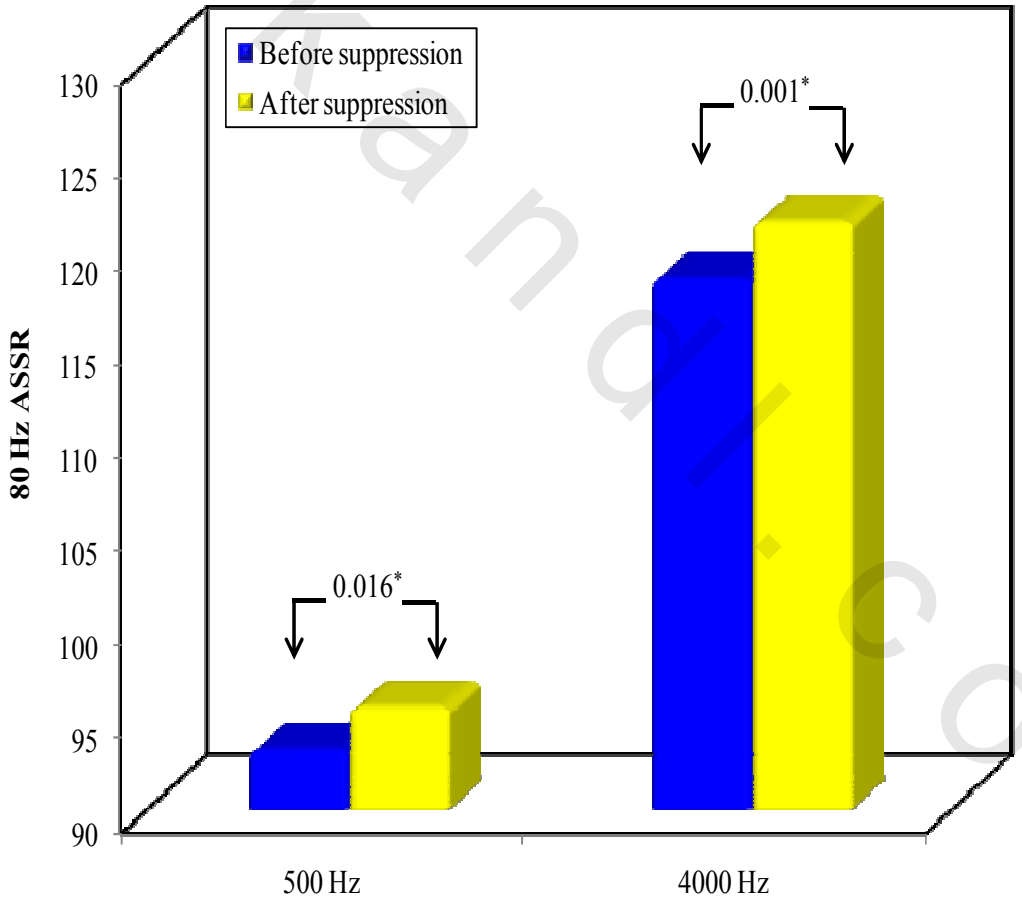

Figure (14): Comparison between ASSR thresholds before and after suppression of 80 Hz ASSR at 500 and 4000 Hz frequencies.