Original Article* / *Çalışma - Araştırma

Assessment of tinnitus with tinnitus severity index, tinnitus handicap inventory and distortion product otoacoustic emissions in patients with normal hearing and hearing loss

İşitmesi normal olan ve işitme kaybı olan hastalarda tinnitus şiddet indeksi, tinnitus handicap envanteri ve distorsiyon ürünü otoakustik emisyonları ile tinnitus değerlendirmesi

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Objectives: This study aims to assess ears with tinnitus and without distortion product otoacoustic emissions (DPOAE) in patients with and without hearing loss and to classify the tinnitus symptoms on the basis of tinnitus severity index (TSI) and tinnitus handicap inventory (THI) in both groups.

Patients and Methods: A total of 102 patients with tinnitus symptoms were included in the study. Of these patients, 48 had (32 males, 16 females; mean age 45±8.9 years) normal hearing and 54 patients (42 males, 12 females; mean age 52±12.1 years) had hearing loss. Pure tone audiogram, high-frequency audiometer and DPOAE were applied to patients. Tinnitus symptoms of patients were assessed with TSI and THI.

Results: Significantly higher tinnitus severity was monitored in group with hearing loss compared with group with normal hearing ($p=0.024$). There was a significant similarity in the frequencies affected from tinnitus between the groups ($p<0.001$). The TSI and THI showed significant similar results between two groups ($p<0.001$). A significant decrease was found in ears with tinnitus in frequencies of 1000 Hz, 2000 Hz, 3000 Hz, 4000 Hz and 6000 Hz with DPOAE compared to the ears without tinnitus in group with normal hearing ($p<0.05$).

Conclusion: Our study results show that patients with TSI and THI are affected by tinnitus at the same rate in daily life whether they have hearing loss or not, but those with hearing loss have a higher tinnitus severity. Decreased DPOAE responses can be found in patients with normal hearing, which can be more profound in low-frequency tinnitus, particularly.

Key Words: Distortion product otoacoustic emission; tinnitus; tinnitus handicap inventory; tinnitus severity index.

Amaç: Bu çalışmada işitmesi normal olan ve işitme kaybı olan hastalarda tinnitus olan ve distorsiyon ürünü otoakustik emisyon (DPOAE) olmayan kulaklar değerlendirildi ve tinnitus semptomları tinnitus şiddet indeksi (TSI) ve tinnitus handikap envanterine (THI) göre her iki grupta da sınıflandırıldı.

Hastalar ve Yöntemler: Çalışmaya tinnitus semptomu olan toplam 102 hasta dahil edildi. Bu hastaların 48'inin (32 erkek, 16 kadın; ort. yaş 45±8.9 yıl) işitmesi normal olup, 54'ünde (42 erkek, 12 kadın; ort. yaş 52±12.1 yıl) işitme kaybı vardı. Hastalara pür ton odyogram, yüksek frekanslı odyometre ve DPOAE uygulandı. Hastaların tinnitus semptomları TSI ve THI ile değerlendirildi.

Bulgular: İşitmesi normal olan gruba kıyasla, işitme kaybı olan grupta anlamlı düzeyde daha yüksek tinnitus şiddeti gözlendi ($p=0.024$). Gruplar arasında tinnitustan etkilenen frekans açısından anlamlı bir benzerlik vardı ($p<0.001$). Tinnitus şiddet indeksi ve THI, iki grup arasında anlamlı düzeyde benzer bulgular gösterdi ($p<0.001$). İşitmesi normal olan grupta tinnitus olmayanlara kıyasla, olan kulaklarda DPOAE ile 1000 Hz, 2000 Hz, 3000 Hz, 4000 Hz ve 6000 Hz frekanslarında anlamlı bir azalma saptandı ($p<0.05$).

Sonuç: Çalışma bulgularımız işitme kaybı olsun veya olmasın, TSI ve THI uygulanan hastaların gündelik yaşamda tinnitustan aynı oranda etkilendiğini, ancak işitme kaybı olanların tinnitus şiddetinin daha yüksek olduğunu göstermektedir. İşitmesi normal olan hastalarda DPOAE yanıtları azalmış olabilir; bu yanıtlar özellikle düşük frekanslı tinnitusta daha belirgin olabilir.

Anahtar Sözcükler: Distorsiyon ürünü otoakustik emisyonu; tinnitus; tinnitus handicap envanteri; tinnitus şiddet indeksi.

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"Tinnitus, which affects 17% of the general population and is seen in 33% of the elderly population, constitutes the primary symptom for 60% of patients presenting to the audiology department.[1,2] Tinnitus is defined as perception of sound without an external stimulus.[3] It is known that tinnitus the pathophysiology of which is not fully understood and the assessment of which is for this reason difficult may accompany almost all disorders occurring in the hearing system.[4] The hearing system has a complex structure consisting of the organ of Corti, afferent and efferent conduction pathways, cortical hearing center and connections providing integration of these. Pathologies developing in any part of these connections lead to increased perception of sound with unknown mechanisms.[5]" Patients describe their tinnitus in different ways. These are whirring, hearing a rapid flow, ringing, roaring and whistling sounds.[6] Measurement of distortion product otoacoustic emissions (DPOAE) is the major method allowing the assessment of mechanical cochlea activity to be properly performed in patients with tinnitus. In these patients, hyperacusia plays an important role and it may frequently be the precursor of tinnitus.[7]

In this study, our objective is to assess ears with and without tinnitus with DPOAE in patients with and without hearing loss while classifying the tinnitus symptoms using the tinnitus severity index (TSI) and tinnitus handicap inventory (THI) in both groups.

PATIENTS AND METHODS

This study was approved through agreement by T.C. Selçuk University Medical Faculty Ethic Commission on 24.04.2013 with 2013/05 meeting number and 2013/123 decision number.

One hundred and two voluntary patients aged 15-70 years who presented to the otorhinolaryngology outpatient clinic of a state hospital with tinnitus symptoms for at least six months regardless of gender and social background differences between January 2013 and July 2013 were included in this study. Forty-eight of them (32 males, 16 females; mean age was 45±8.9 years) were patients with tinnitus with normal hearing (SSO <20 Db) and the remaining 54 participants (42 males, 12 females; mean age was 52±12.05 years) were patients with tinnitus with hearing loss (40 Db >SSO >20 Db).

Detailed anamneses were taken from each case by paying particular attention to the diseases related with otorhinolaryngology, especially tinnitus. Patients having smoking habit, hypertension, diabetes mellitus, cardiovascular disease, hyperlipidemia, hypercholesterolemia, hyperthyroidism, hypothyroidism, head trauma, ear infection, acute and objective tinnitus and known hyperacusia were not included in the study. Four groups consisting of ears with normal hearing and affected or not affected by tinnitus and ears with hearing loss and affected or not affected by tinnitus were created (Table 1).

Pure tone audiometry (250-8000 Hz) and high-frequency audiometry (8000-12000 Hz) were performed as part of the audiological examination. Laterality, frequency and severity of tinnitus were determined with minimum masking level (MML) geared towards white noise stimulus for confirming the lateralization of tinnitus. In patients whose tinnitus symptom was unilateral, measurement was made in the contralateral ear. Sound was emitted to the contralateral ear of the patient and the patient was asked to compare the sound with tinnitus. In patients whose tinnitus symptom was bilateral, measurement was made in the ipsilateral ear. Audiological examination and high-frequency audiometer were performed in a quiet cabin complying with the standard of Industrial Acoustics Company (IAC) by using a Clinical Audiometer AC40 Interacoustics® audiometer (Interacoustics AS, Assens, Denmark).

Distortion product otoacoustic emissions were measured with a tympanogram probe (Echoport ILO292 USB-I Otodynamics® Ltd, UK.) and the ILOv6 software program. Acoustic calibration was made prior to the test. Distortion product otoacoustic emissions were measured in general diagnostic mode by emitting a nonlinear click stimulus. The ratio between f2 and f1 frequencies (f2/f1) was maintained at 1.22. L1 was accepted as

Table 1. Study groups

Group 1:	Normal hearing and tinnitus (-)
Group 2:	Normal hearing and tinnitus (+)
Group 3:	Hearing loss and tinnitus (-)
Group 4:	Hearing loss and tinnitus (+)

f1 frequency for stimulus severity, L2 was accepted as f2 frequency and L1-L2 was kept at the 10 dB sound pressure level (SPL); L1=65, L2=55). Distortion product otoacoustic emissions were measured in 2f1-f2 frequency with a microphone in the external auditory canal and measurements were recorded after impedances were provided by placing a probe into the ear properly at the frequencies of 1, 2, 3, 4, 6 and 7 kHz in the geometric averages of f1 and f2. Minimum primary stimulus creating severity emissions 3 dB SPL higher than noise level as a threshold value for determination of DPOAEs were evaluated as positive on the frequency basis.

Tinnitus severity index and THI were completed for all patients who complied with the criteria.

Tinnitus severity index is an assessment questionnaire consisting of 12 questions and a rating system of scores 0-5. Patients were assessed on the basis of 60 points. Patients who received 1-12 points were classified as very mild, 13-24 points as mild, 25-36 points as moderate, 37-48 points as severe, 49-60 points as catastrophic.

Tinnitus handicap inventory is an assessment questionnaire consisting of 25 questions and a rating system with scores 0-1-2. Patients were assessed on the basis of 100 points. Zero-16 points were classified as weak (It is heard only in a quiet environment), 18-36 as medium (It may be masked easily with noise in the environment and it may be forgotten easily with activity), 38-56 as moderate (Patient may still perform his/her daily activities although noise coming back is heard), 58-76 as severe (It is heard nearly all the time, it disturbs the sleeping and it may prevent daily activities), 78-100 as catastrophic (It is heard all the time, it disturbs sleep and causes difficulties in daily activities).

Statistical analysis

Statistical analysis was carried out using the SPSS version 13.0 software for Windows (SPSS Inc., Chicago, Illinois, USA). All quantitative variables were estimated using measures of central location (i.e. mean and median) and measures of dispersion (i.e. standard deviation; SD). Data normality was checked using the Kolmogorov-Smirnov tests of normality. One-way of analysis (ANOVA) was used for comparing the intergroup quantitative data. The groups which had differences among each other were determined via Post-hoc Tukey HSD (honestly significant difference). Pearson correlation analysis was used for the purpose of examining the correlation among data within group. $P<0.05$ was accepted as statistically significant.

RESULTS

In the group with normal hearing, bilateral tinnitus was observed in six of 48 patients (12.5%), in the left ear of 26 patients (54.1%), and in the right ear of 16 patients (33.3%). In the group with hearing loss, bilateral tinnitus was seen in four of 54 patients (7.4%), in left ear in 34 patients (62.9%) and in right ear in 16 patients (29.6%).

In the group with normal hearing, tinnitus severity was observed in range of 20 dB-100 dB (average: 49.79±20.71), tinnitus frequency in range of 250-8000 Hz (average: 4791.66±2914.23), TSI in range of 14-55 (average: 33±12), THI in range of 4-78 (average: 44±22). In the group with hearing loss, tinnitus severity was observed in range of 20 dB-115 dB (73.70±20.36 in average), tinnitus frequency in range of 250-8000 Hz (4828.70±2749.37 in average), TSI in range of 12-60 (32±12 in average), THI in range of 4-84 (41±25 in average). It was observed that frequencies affected by tinnitus were the same for two groups and this was statistically significant ($p<0.001$). Tinnitus severity index and THI results showed a significant similarity between two groups ($p<0.001$).

Ears with and without tinnitus in the group with normal hearing and ears with and without tinnitus in the group with hearing loss were measured with DPOAE and were compared (Figure 1). No significant differences were seen among all groups in terms of tinnitus frequency (Hz) ($p=0.798$). In the group with hearing loss in terms of tinnitus severity (dB), an increased difference at a statistically significant level was seen as compared with the group with normal hearing ($p=0.024$). In the group with normal hearing, a significant decrease was found in ears with tinnitus in frequencies of 1000 Hz, 2000 Hz, 3000 Hz, 4000 Hz and 6000 Hz with DPOAE between the hearing capacities of ears with and without tinnitus in the group with normal hearing ($p<0.05$). In the group with hearing loss,

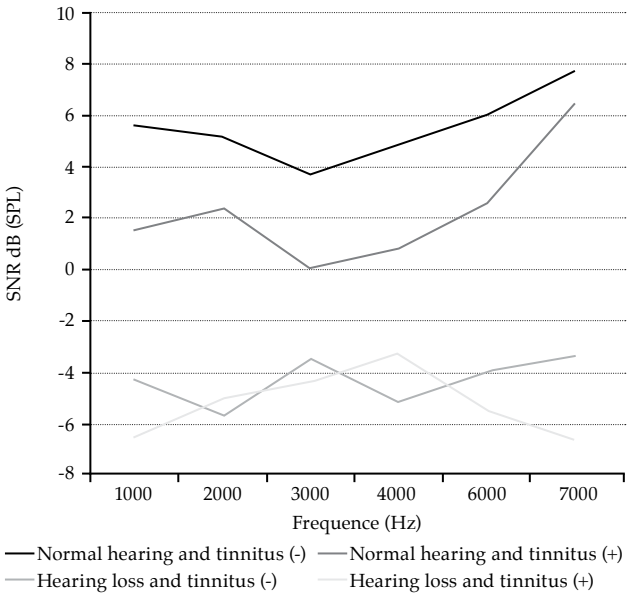

Figure 1. *Study groups distortion product otoacoustics emissions results. SNR: Signal to noise ratio; SPL: Sound pressure level.*

no significant differences were observed in DPOAE in terms of tinnitus in patients with hearing loss (p>0.05) (Table 2).

DISCUSSION

The prevalence of tinnitus varies in each age group and characteristically increases with age. Tinnitus is mostly seen in the age range of 30-70 years throughout life.[8] In our study, the average age of all participants was 49±11; it was within the generally accepted limits.

In the study conducted by Tyler,[9] spontaneous otoacoustic emissions (OAE) was found in only one of 25 patients and it was reported that there were no associations between spontaneous OAE and pitch and severity of tinnitus In recent years, studies have been conducted investigating the association between DPOAE and tinnitus.[9,10] These studies found a significant correlation between the frequency at which tinnitus developed and DPOAE responses. They explained this difference with the effect of external pileous cells on the development of tinnitus or the effect of tinnitus-causing generator on the activation of external pileous cells.[10] We deemed it suitable to use DPOAE in our study by taking these results into consideration.

Both genders are affected by tinnitus equally and tinnitus is bilateral in 50% of patients.[8] In the study by Briner et al.,[8] the ratio of males to females was 2:42 whereas in the study by Yılmaz et al.,[11] this rate was found to be 1:86 and bilateral tinnitus was encountered in 42.5% of patients. The male: female ratio in our study was 2.64 and was consistent with literature. When we examined tinnitus localization, bilateral tinnitus was found in only 10 patients (9.8%). It is accepted by authorities that tinnitus frequency is generally above 2000 Hz, it peaks between 3000 and 4000 Hz and it is mostly found at 4000 Hz.[11] Briner et al.,[8] found the average value of tinnitus frequencies to be 2718 Hz. Yılmaz et al.,[11] found the average value of tinnitus frequencies as 5796.67±3017.89 Hz. Tinnitus frequency varies from day to day even within the same day in one out of every two patients and they attributed these differences in the results to this situation.[11] In our study, this average value was found to be 4791.66±2914.23 in the group with normal hearing and 4828.70±2749.37 in the group with hearing loss. Thus, it was seen that frequencies affected by tinnitus were similar between both groups and this was statistically significant (p<0.001).

In a study of 3,600 participants, Axelsson and Ringdahl[12] reported that tinnitus severity was higher in those with hearing loss compared to those with normal hearing and the discomforts related to sleeping increased with the severity of tinnitus. In our study, a statistically significant increased difference was seen in the group with hearing loss in terms of tinnitus severity (dB) (73.70±20.36 in average) compared to the group with normal hearing (49.79±20.71 in average), which is consistent with literature (p=0.024).

Table 2. Distortion product otoacoustics emissions statistical results among groups

DPOAE (Hz)	1000	2000	3000	4000	6000	7000
	p	*p*	*p*	*p*	*p*	*p*
Normal hearing and tinnitus (-)/(+)	0.039	0.037	0.024	0.043	0.047	0.169
Hearing loss and tinnitus (-)/(+)	0.175	0.934	0.987	0.984	0.616	0.138

DPOAE: Distortion product otoacoustics emissions.

There is a close relation between tinnitus and hearing loss.[13] Spoendlin[14] found the presence of tinnitus in 50% of patients with sensorineural hearing loss, 70% of those with presbycusis, 30-90% of those with ototoxicity, 50-90% of those with chronic acoustic trauma and 100% of Meniere patients. Stouffer et al.,[15] reported that 52% of patients complained of bilateral tinnitus, 37% of unilateral tinnitus, with 10% within the head and less than 1% out of head, and that left ear tinnitus was more frequently seen in both women and men. Anatomical structures and differences in the right and left central nerve system physiology were showed as a reason for this result.[16] It was showed that the left ear was more sensitive to many cochlear injury reasons such as noise and ototoxic drugs.[17,18] In our study, tinnitus was seen in left ear at a rate of 54.1% in the group with normal hearing and at a rate of 62.9% in the group with hearing loss.

"Objective" and "subjective" tinnitus classifications are the most common among etiologic classifications.[19] The most important character of objective tinnitus is that sounds disturbing the patient are heard by other persons. Subjective tinnitus is perceived only by patients and cannot be heard by other persons and this is the type that is frequently seen.[20] Measurement of tinnitus is performed in four steps consisting of pitch matching, loudness matching, minimal masking level and residual inhibition.[21] In our study, measurement of side, severity and frequency of tinnitus was performed according to these steps.

The tinnitus handicap inventory is an assessment questionnaire consisting of 25 questions and it aids in the determination of the effect of tinnitus on daily life.[22] The tinnitus severity index assesses tinnitus by measuring the negative effects caused by tinnitus on the patient.[23] The tinnitus severity index measures the psychological and emotional effects of tinnitus at a rate of 50%, effects on lifestyle at a rate of 37% and effects specific to tinnitus at a rate of 17%.[23] In our study, "medium" symptoms in TSI results and "moderate" symptoms in THI scores were seen in the group with normal hearing and the group with hearing loss. This shows that patients are affected by tinnitus at the same rate in a statistically significant way whether they have hearing loss or not in daily life ($p<0.001$). Our article has importance as the first study conducted in the literature in this regard.

Vernon and Moller[24] found that emissions of persons with tinnitus symptoms in the left ear were lower compared with those with tinnitus symptoms in right ear. In the studies conducted, they reported lower DPOAE amplitudes in 93.3% of the cases with tinnitus and full hearing especially for the frequencies of 4-7 kHz compared with the group without tinnitus.[25] In the study conducted by Mauermann et al.,[26] it was observed that DPOAE recorded in people with normal hearing but having no tinnitus was low at a significant level as compared with those having no tinnitus symptoms. In our study, in the group with normal hearing, a significant decrease was found in ears with tinnitus in the frequencies of 1000 Hz, 2000 Hz, 3000 Hz, 4000 Hz and 6000 Hz with DPOAE based on a comparison between hearing capacity of ears with and without tinnitus in the group with normal hearing ($p<0.05$) (Table 2). Also, tinnitus frequency was in range of 250-8000 Hz (4791.66±2914.23 Hz in average) in the group with normal hearing, it was consistent with frequencies that had a significant DPOAE decrease. This result may lead us to think that possibility of external pileous cells being affected and being the origin for tinnitus is high if tinnitus frequency is low (<6000 Hz) in tinnitus patients with normal hearing.

Linke et al.[27] found a decrease in DPOAE responses in high frequencies among tinnitus patients with hearing loss. In our study, DPOAE values were observed low as expected in the group with hearing loss. Nevertheless, in the group with hearing loss, no significant differences were observed in DPOAE in terms of tinnitus in patients with hearing loss ($p>0.05$) (Table 2).

Conclusion

In our study, we showed that tinnitus patients are affected by tinnitus at the same rate whether they have hearing loss or not with TSI and THI and they were affected in the same frequencies in DPOAE but those with hearing loss had higher tinnitus severity. In patients with tinnitus and with normal hearing, DPOAE is able to assess functional activity of external plecious cells objectively and provide valuable information about localization of generator focus leading

to tinnitus. It was seen that decreased DPOAE responses were found in patients with tinnitus and with normal hearing and this decrease emerged more significantly in low-frequency tinnitus. Consequently, we are of the opinion that further studies intended for tinnitus treatment are necessary.

Declaration of conflicting interests

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