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Original Article

The Effect of Postmenopausal Osteoporosis on Middle Ear Resonance Frequency

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BACKGROUND: The effect of postmenopausal osteoporosis on the middle ear mechano-acoustic system is unknown. The aim of this study is to investigate whether or not middle ear resonance frequency is affected in females with postmenopausal osteoporosis.

METHODS: The study included postmenopausal women aged 45-60 years, separated into 2 groups as females with postmenopausal osteoporosis and healthy postmenopausal females (control group). A detailed anamnesis was taken from all subjects and then the ear, nose, and throat examinations were done followed by pure tone audiometry, tympanometry, and multifrequency tympanometry tests. The groups were compared in respect of pure tone average, bone conduction threshold, RF, static admittance, and tympanometric peak pressure values.

RESULTS: The mean age of the patients was 59.2 ± 4.53 years (range, 48-65 years) in the postmenopausal osteoporosis group and 57.11 ± 4.27 years (range, 48-65 years) in the control group ($P > .05$). The mean resonance frequency values for the postmenopausal osteoporosis and control group were 954.41 ± 127.47 and 935.29 ± 126.39 Hz ($P > .05$). The mean static admittance values for the postmenopausal osteoporosis and control group were 0.82 ± 0.33 and 0.85 ± 0.3 mmho, and mean tympanometric peak pressure values were −7.35 ± 18.52 and −6.94 ± 19.52 daPa ($P > .05$ for both static admittance and tympanometric peak pressure). The mean pure tone averagevalues for the postmenopausal osteoporosis and control group were 20.96 ± 6.82 and 15.60 ± 7.81 dB, and mean bone conduction threshold values were 17.57 ± 6.03 and 12.10 ± 6.52 dB ($P < .05$ for both pure tone average and bone conduction threshold).

CONCLUSIONS: The results showed that the middle ear resonance frequency values were not affected in postmenopausal osteoporosis patients, but there was seen to be greater sensorineural hearing loss in females with postmenopausal osteoporosis compared to healthy postmenopausal females.

KEYWORDS: Hearing loss, middle ear ossicles, multifrequency tympanometry, postmenopausal osteoporosis, resonance frequency

INTRODUCTION

Ostroporosis is a bone disease defined as increased bone fragility and increased risk of fracture associated with low bone mass and impaired bone microstructure.[1] Females constitute 80% of osteoporosis cases, and the majority of these are in the postmenopausal period. This disease, which develops in females due to estrogen deficiency in the postmenopausal period, is known as postmenopausal osteoporosis (POP). As POP is a systemic disease, all the bones in the body are affected.[2]

Previous studies have shown that the temporal bone is affected by POP and this is related to sensorineural hearing loss.[3,4] However, the effect on the middle ear ossicles is unknown. The potential effect of POP on ossicles can cause a deterioration of stiffness and mass in the middle ear mechano-acoustic system, and this potential impairment can be revealed with immittancemetric measurements.

Classic immittancemetry is an economical and non-invasive test allowing the evaluation of acoustic admittance in the middle ear. A change in air pressure in the external ear canal provides a dynamic measurement of acoustic admittance. Classic immittancemetry in current use is usually applied with a 226 Hz probe tone. Multifrequency tympanometry is a method that provides the analysis of tympanograms obtained with probe tones varying between 226 Hz and 2000 Hz. High-frequency probe tones are extremely valuable in the determination of pathologies that change the stiffness and mass effect of the middle ear system.[5] One of

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the important parameters of multifrequency tympanometry is resonance frequency (RF). RF is the frequency with the lowest resistance and the highest vibration of the middle ear system and is affected by changes in mass and hardness occurring in the middle ear mechanoacoustic system.[6]

The aim of this study was to investigate whether or not the RF, TPP, and SA of the middle ear were affected through the application of multifrequency tympanometry tests in POP patients without air-bone gap.

MATERIALS AND METHOD

This research was approved by the Baskent University Medical and Health Sciences Research Committee and was supported by the Baskent University Research Fund. Informed consent was obtained from all the study participants. This prospective, controlled clinical study was conducted in the Audiology Unit of the Ear, Nose, and Throat Diseases Department. The participants were separated into 2 groups, as those aged 45-60 years diagnosed with POP, and age-matched, healthy, postmenopausal volunteers.

The diagnosis of osteoporosis in the postmenopausal females was made from the determination of the T-score value in the bone mineral density measurements taken with the dual x-ray absorptiometry (DXA) technique. Based on the World Health Organization (WHO) criteria,[7] a T-score of <-2.5 was evaluated as postmenopausal osteoporosis. The control group was formed of postmenopausal women with a T-score of >-1.

The patients with postmenopausal osteoporosis included in the study were those with no external ear canal or tympanic membrane pathology determined in the otoscopic examination, no history of ear disease or ear surgery, had not previously received any treatment which could affect bone metabolism, had middle ear pressure in the limits of $\pm$50 daPa in the electroacoustic immittancemetry evaluation, had a type A tympanogram, and had no conductive or mixed type hearing loss in the audiometric examination. Audiograms with air-bone gap >10 dB at least 1 frequency were evaluated as a conductive hearing loss if the bone thresholds were <20 dB at all frequencies, and mixed hearing loss if the bone thresholds were $\geq$20 dB at least one frequency, and these patients were excluded from the study. Patients with any systemic chronic disease were excluded from the study. First, an ear, nose, and throat (ENT) examination was applied by an ENT specialist, and a detailed history was taken. Patients deemed suitable for inclusion in the study as a result of this examination were then applied with pure tone audiometry, tympanometry, and multifrequency tympanometry tests.

Pure Tone Audiometry

The pure tone audiometry was applied in quiet rooms according to the standards of the *Industrial Acoustic Company (IAC) Inc.* using a *Clinical Audiometer AC40* device (*Interacoustics, Assens, Denmark*). The determination of the type and degree of hearing loss was based on pure tone average (PTA). By determining the air and bone conduction thresholds (BCT) at 500, 1000, and 2000 Hz, the PTA values for both ears were obtained separately. The *Northern and Downs* classification[8] was used for the classification of hearing loss. According to this classification, a pure tone average less than 16 dB is accepted as normal hearing, 16-25 dB slight hearing loss, 26-30 dB mild hearing loss, 31-50 dB moderate hearing loss, 51-70 db severe hearing loss, 70 dB and above profound hearing loss.

Immittancemetric Measurements

The immittancemetric measurements of the study participants were taken using a *GSI Tympstar Version 2 (Grason Stadler Inc., MN, USA)* electroacoustic immittancemeter. Using a 226 Hz probe tone, the tympanogram and static admittance values were recorded. The tympanogram entries are recorded at air pressure varying between +200 and 400 daPa at the rate of 200 daPa/s. In patients determined with type A tympanogram, multifrequency tympanometry measurements were taken.

The device takes the multifrequency tympanometry measurement in two stages. In the first step, standard tympanometry data are investigated such as static admittance (SA), tympanometric peak pressure (TPP), and gradient value by giving a fixed frequency probe tone, changing the pressure between 200 and $-$400 daPa, and the tympanogram is obtained. In the second step, by keeping the pressure constant, the middle ear RF value is determined by stimulating each ear in the frequency range of 250-2000 Hz consecutively at 50 Hz intervals. At the end of the test, the outputs were recorded together with other immittancemetric values.

Statistical Analysis

In the biostatistical analysis, it was calculated to be necessary to have at least 32 subjects in the study group and 32 in the control group for the power of the study to be $\geq$0.90. Data obtained in the study were analyzed statistically using SPSS v. 22.0 (IBM SPSS Corp.; Armonk, NY, USA). All data were recorded, and the arithmetic mean, standard deviation, minimum and maximum values were calculated. Normality of the variables and homogeneity was evaluated with the Levene test. In the comparison of mean values between groups, the Student's *t*-test was applied. A value of $P < .05$ was accepted as statistically significant.

RESULTS

Evaluation was made for 146 ears of 73 postmenopausal women, as 74 ears of 37 women in the POP group and 72 ears of 36 control group women. Two women (4 ears) from the POP group and 2 women (4 ears) from the control group were excluded because of mixed hearing loss. One woman (2 ears) from the POP group was also excluded because of conductive hearing loss. As a result, the data of 136 ears of 68 women (34 women in control group and 34 women in study group) were used for analysis.

The mean age of the participants was 59.2 $\pm$ 4.53 years (range, 48-65 years) in the POP group and 57.11 $\pm$ 4.27 years (range, 48-65 years) in the control group. No statistically significant difference was determined between the groups in respect of age ($P = .53$).

The mean PTA value was 20.96 $\pm$ 6.82 dB in the POP group (68 ears) and 15.60 $\pm$ 7.81 dB in the control group (68 ears) ($P < .05$). The mean BCT value was 17.57 $\pm$ 6.03 dB in the POP group (68 ears) and 12.10 $\pm$ 6.52 dB in the control group (68 ears) ($P < .05$). In both the PTA and BCT values, a statistically significant difference was determined in the comparisons of the POP group and the control group (Table 1).

Normal hearing was found in 43 ears (63%), slight hearing loss in 17 ears (25%), mild hearing loss in 3 ears (4.5%), and moderate

Table 1. Audiological Values of POP and Control Group

	Groups		*P*
	POP (n = 68 ears)	Control (n = 68 ears)	
Age (years)	59.2 ± 4.53	57.11 ± 4.27	.53
PTA (dB)	20.96 ± 6.82	15.60 ± 7.81	**<.001**
BCT (dB)	17.57 ± 6.03	12.10 ± 6.52	**<.001***
RF (Hz)	954.41 ± 127.47	935.29 ± 126.39	.381**
SA (mmho)	0.82 ± 0.33	0.85 ± 0.3	.463
TPP (daPa)	−7.35 ± 18.52	−6.94 ± 19.52	.237

POP, post-menopausal osteoporosis; PTA, pure tone average; BCT, bone conduction threshold; RF, resonance frequency; SA, static admittance; TPP, tympanometric peak pressure; dB, decibel; Hz, hertz; daPa, decapascal. Values are given in mean ± SD.
*In PTA values, a statistically significant difference was determined in the comparisons of the POP group and the control group; **In BCT values, a statistically significant difference was determined in the comparisons of the POP group and the control group.

hearing loss in 5 (7.5%) ears of the control group. In the POP group, normal hearing was found in 20 ears (29.5%), slight hearing loss in 33 ears (48.5%), mild hearing loss in 7 ears (10.5%), and moderate hearing loss in 8 ears (11.5%) (Figure 1). None of the individuals included in the study had severe or profound hearing loss.

The mean RF value was 954.41 ± 127.47 Hz in the POP group (68 ears) and 935.29 ± 126.39 Hz in the control group (68 ears) ($P > .05$). In the RF values, no statistically significant difference was determined in the comparisons of the POP group and the control group (Table 1).

The mean SA value was 0.82 ± 0.33 mmho in the POP group (68 ears) and 0.85 ± 0.30 mmho in the control group (68 ears) ($P > .05$). The mean TPP value was −7.35 ± 18.52 daPa in the POP group (68 ears) and −6.94 ± 19.52 daPa in the control group (68 ears) ($P > .05$). In the SA and TPP values, no statistically significant difference was determined in the comparisons of the POP group and the control group (Table 1).

In the PTA, BCT, RF, SA, and TPP values, no statistically significant difference was determined in the comparisons of the right and left ear of the POP group. All mean audiological values of right and left ears in the POP group are shown in Table 2. In the PTA, BCT, RF, SA, and TPP values, no statistically significant difference was determined in the comparisons of the right and left ear of the control group. Mean audiological values of right and left ears in the control group are shown in Table 3.

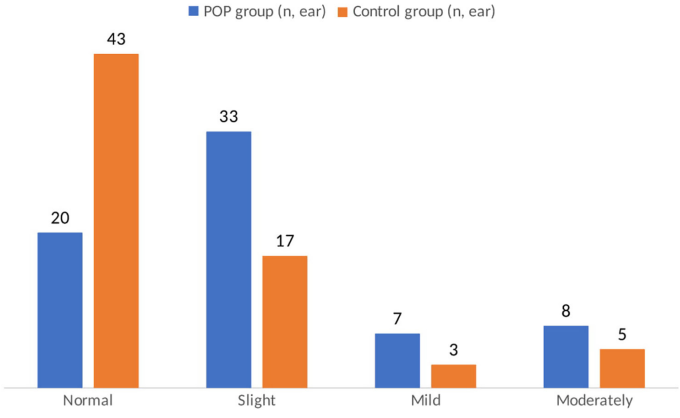

Figure 1. Distribution of degree of hearing loss according to groups.

Table 2. Audiological values of right and left ears in the POP group.

	POP Group		*P*
	Right Ear (n = 34)	Left Ear (n = 34)	
PTA (dB)	20.05 ± 5.43	21.85 ± 7.9	.282
BCT (dB)	17.26 ± 5.26	17,88 ± 6.77	.676
RF (Hz)	945.58 ± 133.35	963.23 ± 122.6	.572
SA (mmho)	0.81 ± 0.34	0.82 ± 0.32	.927
TPP (daPa)	−7.12 ± 17.57	−7.59 ± 19.70	.423

POP, post-menopausal osteoporosis; PTA, pure tone average; BCT, bone conduction threshold; RF, resonance frequency; SA, static admittance; TPP, tympanometric peak pressure; dB, decibel; Hz, hertz; daPa, decapascal. Values are given in mean ± SD.

Table 3. Audiological Values of Right and Left Ears in the Control Group

	Control Group		*P*
	Right Ear (n = 34)	Left Ear (n = 34)	
PTA (dB)	14.77 ± 6.74	15.77 ± 9.06	.613
BCT (dB)	12.12 ± 5.95	12.09 ± 7.12	.985
RF (Hz)	922.85 ± 6.74	944.28 ± 125.3	.392
SA (mmho)	0.86 ± 0.32	0.84 ± 0.28	.492
TPP (daPa)	−6.97 ± 19.33	−6.91 ± 20.01	.713

PTA, pure tone average; BCT, bone conduction threshold; RF, resonance frequency; SA, static admittance; TPP, tympanometric peak pressure; dB, decibel; Hz, hertz; daPa, decapascal. Values are given in mean ± SD.

DISCUSSION

Postmenopausal osteoporosis is a systemic disease, characterized by reduced bone mass and increased bone turnover, which affect all bones in the body. As all the bones of the skull are affected by osteoporosis, the temporal bone and otic capsule are also affected.[9] However, the effect of osteoporosis on the middle ear ossicles and sound transmission is not clear. The internal structure of middle ear ossicles is formed of compact bone, bone lacunae, and cartilaginous nodules. In a histomorphological study of 52 ear ossicles, Sarrat et al[10] showed that there was a great difference between specimens in respect of the degree of these cavitations and these increased with increasing age. In another study, high-resolution CT showed that the middle ear ossicles of patients with osteoporosis were affected.[11] Although Kumar et al reported that the osteoporotic process affected middle ear resonance frequency, no significant air-bone gap was determined in the audiometry test in the same study.[12] In the current study, no significant difference was determined between POP patients without air-bone gap and the healthy postmenopausal women in respect of middle ear RF, SA, and TPP values. This finding demonstrates that the middle ear ossicles were not affected by POP to an extent to change the RF.

Significantly greater sensorineural hearing loss was determined in the POP group than in the control group in this study ($P < .05$). Several previous studies have shown a relationship between osteoporosis in the postmenopausal period and sensorineural hearing loss.[3,4,13-15] Demineralization of the otic capsule and cochlea has been shown to be responsible for the sensorineural hearing loss in these patients, and as demineralization increases, so hearing loss also increases.[16,17]

Pathologies affecting the middle ear ossicle chain cause an air-bone gap in pure tone audiometry.[18] There is also a possibility that the potential loss of mass in the ossicles associated with osteoporosis is a reason for the air-bone gap in audiometry. As it is difficult to differentiate other ossicle chain problems that affect the air-bone gap, subjects with conductive or mixed type hearing loss were excluded from this study to avoid bias. In the current study, patients with air-bone gap >10 dB at least in 1 frequency were excluded from the study. Although this exclusion criteria were relatively strict, only 3 of 37 POP patients were excluded for this reason. It may have been better to discount other ossicle chain pathologies by taking high-resolution CT of patients with conductive or mixed type hearing loss and then they could have been included in the study.

CONCLUSION

The results of this study showed that there was significantly more sensorineural hearing loss in the POP group than in the control group. The data also showed that the middle ear RF, SA, and TPP of POP patients without air-bone gap were not affected. This demonstrates that the postmenopausal osteoporotic process does not affect the middle ear ossicles to an extent that will change the multifrequency tympanometry in POP patients with sensorineural hearing loss. Nevertheless, there is a need for further controlled histomorphological studies to more accurately determine to what extent the middle ear ossicles are affected in POP patients.

Ethics Committee Approval: This study was approved by Baskent University Institutional Review Board and Ethics Committee (Project no: KA 17/289).

Informed Consent: Informed consent was obtained from all the study participants.

Peer Review: Externally peer-reviewed.

Author Contributions: Materials, Data Collection and/or Processing, Analysis, Literature Review, Writing – B.B.; Conseption, Supervision, Writing, Critical Review – S.J.; Conseption, Design, Supervision, Critical Review – S.S.E.

Conflict of Interest: The authors have no conflict of interest to declare.

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