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Investigation of ambient-pressure absorbance characteristics of cartilage-grafted tympanic membranes

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Main Article

Beyza Asta takes responsibility for the integrity of the content of the paper

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Abstract

Objective. To investigate alterations in middle-ear mechanics after type 1 cartilage tympanoplasty by comparing the ambient pressure absorbance values of the perforated tympanic membrane, normal tympanic membrane and cartilage-grafted tympanic membrane.
Methods. Twenty patients diagnosed with non-suppurative chronic otitis media and 20 healthy controls were included. Pure tone audiometry and wideband tympanometry were performed once in the healthy controls and pre-operatively, one month and three months post-operatively in the patients.
Results. Using wideband tympanometry, the patients' three-month post-operative ambient pressure absorbance values were found to be similar to those of the healthy controls at low frequencies, while lower ambient pressure absorbance values were recorded at middle and high frequencies. Air–bone gap and ambient pressure absorbance values showed significant negative correlations at 1000 and 4000 Hz both pre- and post-operatively.
Conclusion. Generally, the patients' ambient pressure absorbance values were significantly lower at middle and high frequencies than those of the healthy controls. Post-operative wideband tympanometry is a practical tool for investigating the effects of a repaired tympanic membrane on middle-ear dynamics.

Introduction

Tympanoplasty is a surgical method used to eradicate disease from, and restore the function of, the middle ear.[1] Conventional tympanometry is the 'gold standard' test to examine middle-ear status.[2] A pure tone stimulus is used in conventional tympanometry. However, wideband tympanometry, which is a newer method, uses a click stimulus that covers a wide frequency range (e.g. 226–8000 Hz).[3] Hence, it is more sensitive and provides more detailed information about middle-ear structures and disorders.

Wideband tympanometry absorbance graphs can be created in two ways: using data obtained under pressurised and non-pressurised conditions. This means that wideband tympanometry can be used to objectively analyse the effectiveness of a surgical procedure in the early post-operative period at ambient pressure, without the need to apply tympanometric pressure to the ear canal.[3]

The aim of this study was to investigate alterations in middle-ear mechanics in the early post-operative period following type 1 cartilage tympanoplasty. We compared pre-operative and early post-operative ambient pressure absorbance values, and we also compared the ambient pressure absorbance values of patients and healthy individuals. The correlation between post-operative hearing improvements and ambient pressure absorbance values was also investigated.

Materials and methods

Study design

This prospective case–control study was conducted in the Audiology Unit of the Otorhinolaryngology Department of the Faculty of Medicine of Erciyes University. The study protocol was approved by the Ethics Committee of Ankara Yıldırım Beyazıt University (10 October 2018, decree no. 16). All participants included in the study provided their verbal and written informed consent. The principles of the Declaration of Helsinki were followed during the study.

Study population

Forty-seven patients who were diagnosed with non-suppurative chronic otitis media, were older than 18 years of age and planned to have type 1 cartilage tympanoplasty were recruited as potential participants. All 47 candidates had external auditory canals that were deemed suitable for the tests to be employed and good mastoid aerations (detected with temporal computerised tomography). The exclusion criteria were previous ear surgery, any middle-ear pathology other than tympanic membrane perforation and the presence of post-operative tympanic membrane perforation.

Among the 47 candidates, middle-ear pathologies other than tympanic membrane perforation were detected during surgery in 25 patients and 2 patients had post-operative tympanic membrane perforations; they were excluded from the study. Finally, 20 patients were included in the study group. Of the 20 patients included in the study, 14 had subtotal and 6 had central tympanic membrane perforations.

Twenty individuals without any otological disorders and with normal hearing were included in the control group.

Detailed medical histories of all participants were obtained, their medical records were reviewed and they underwent a complete otorhinolaryngological examination.

Surgical technique

Type 1 cartilage tympanoplasty was performed under general anaesthesia through a post-auricular incision. After its perichondrium was peeled off, the cartilage graft was sliced into strips and the palisade technique was used to repair the tympanic membrane perforation. It was ensured that the graft was in contact with the malleus. For the cartilage graft, tragal cartilage was used in six patients, cymba concha cartilage was used in eight patients and cavum concha cartilage was used in six patients. Enough graft cartilage to just cover the tympanic membrane perforation was used, but the total amount used was not measured.

The anatomical success of the surgery was determined by assessing whether the healed graft showed any tympanic membrane perforation in the post-operative period. The functional success was evaluated by assessing the post-operative hearing gain.

Audiological tests

Pure tone audiometry and wideband tympanometry were performed in the study and control groups. The audiological tests were performed once in the control group and three times in the study group: pre-operatively, and one and three months after surgery.

Pure tone audiometry

A pure tone audiometry test was performed with an Otometrics Madsen Astera 2 clinical audiometer device. Pure tone air-conduction thresholds were determined in the 125–8000 Hz range using TDH-39 earphones. Bone-conduction thresholds were determined in the range of 500–4000 Hz using a RadioEar B71 bone conduction vibrator. The pure tone average (PTA) for air conduction was calculated as the mean of the air-conduction thresholds at 500, 1000, 2000 and 4000 Hz. The mean air–bone gap (ABG) was calculated by subtracting the mean bone-conduction value from the mean air-conduction value. The air-conduction hearing gain was calculated by subtracting the pre-operative mean air-conduction value from the post-operative mean air-conduction value.

Wideband tympanometry

Wideband tympanometry measurements were recorded using an Interacoustics Titan wideband tympanometer device. The probe was placed in the external ear canal and the measurements were obtained via computer software that recorded the data. The measurements were recorded automatically in a database, and a 21.5-Hz click stimulus with a 2-ms duration and a frequency range of 226–8000 Hz was used. The wideband tympanometry stimulus was set at a 100 dB peSPL (decibels peak equivalent sound pressure level) (∼65 dB nHL (decibels normal hearing level)) intensity level, and a non-pressurised measurement method was used.

The obtained data were transferred into a Microsoft Office Excel file for analysis. All data (ambient pressure absorbance values) recorded in this file were transferred to the SPSS Statistics software platform (IBM, Armonk, New York, USA) and analysed. The pre-operative and one- and three-month post-operative ambient pressure absorbance values of the study group were compared. The ambient pressure absorbance values of the study group were also compared with the ambient pressure absorbance values of the control group.

Statistical analysis

The data were analysed with the SPSS Statistics Standard Concurrent User V 25 statistical package program (IBM). Descriptive statistics are presented as number of units (*n*), percentage and mean ± standard deviation $\overline{(}$ ± SD). The normality of the distribution of the numerical data was analysed using the Shapiro–Wilk test of normality and Q–Q graphs. Homogeneity of variances was analysed using Levene's test. The ages of the groups were compared using the two independent samples *t*-test, and the distributions of gender and the side of the operated ear were compared using the exact method of the Pearson chi-square (χ^2) test.

The comparison of the pre-operative, one-month post-operative, and three-month post-operative measurements of the study group was conducted using two-way analysis of variance in repeated measurements, a general linear model. When a difference was found using two-way analysis of variance, the main effect comparisons were performed using Bonferroni correction for multiple comparisons. Statistical significance was set at $p < 0.05$.

Results

The study group consisted of 9 (45.0 per cent) men and 11 (55.0 per cent) women, and the control group consisted of 8 (40.0 per cent) men and 12 (60.0 per cent) women. The gender distribution was similar in the 2 groups ($\chi^2 = 0.102$, $p = 1.000$). The mean age was 39.8 ± 15.7 years (range, 20–67 years) in the study group and 35.3 ± 9.8 years (range, 21–57 years) in the control group, without any significant difference between the groups ($t = 1.099$, $p = 0.280$). Seven (35.0 per cent) right ears and 13 (65.0 per cent) left ears were included in the study group, and 9 (45.0 per cent) right ears and 11 (55.0 per cent) left ears were included in the control group. The groups showed statistically similar distributions in terms of the side of the ear ($\chi^2 = 0.417$, $p = 0.748$).

The rate of anatomical success (i.e. complete closure of the tympanic membrane perforation) was 90.9 per cent (20 out of 22) at the three-month post-operative time point. As mentioned above, two patients with graft failure were excluded from the study.

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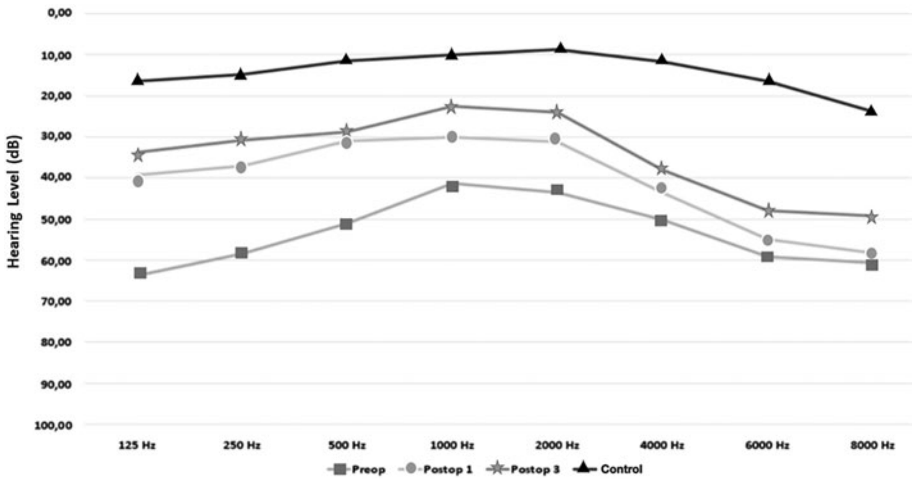

Figure 1. Pure tone audiometry results.

Pure tone audiometry results

The pre-operative and 1- and 3-month post-operative pure tone thresholds of the study group members were examined at 125, 250, 500, 1000, 2000, 4000, 6000 and 8000 Hz. The values are presented in Figure 1, where they are compared with those of the control group members. The pre-operative, 1-month post-operative, and 3-month post-operative PTAs of the study group were 46.75 ± 12.47, 33.1 ± 16.64 and 28.4 ± 12.03 dB, respectively, while the PTA was 10.5 ± 3.56 dB in the control group. Although the air-conduction thresholds of the patients in the study group improved significantly during the post-operative period ($p < 0.001$ at both 1 month and 3 months), they were significantly higher than those in the control group.

When the ABGs of the groups were compared, the pre-operative and 1- and 3-month post-operative pure tone mean ABGs of the study group were 25.88 ± 9.31, 14.25 ± 6.78 and 10.88 ± 5.66 dB, respectively, while the pure tone mean ABG was 2.0 ± 1.31 dB in the control group. The ABG values of the study group were significantly higher than those of the control group at all time points ($p < 0.001$ for all). In addition, it was evident that the ABG value was significantly lower at the 3-month post-operative time point compared with that at the 1-month post-operative time point in the study group ($p < 0.001$) (Figure 2).

Wideband tympanometry results

The participants' ambient pressure absorbance values, obtained between 226 and 8000 Hz, are presented in Figure 3 and Table 1. In the control group, the lowest ambient pressure absorbance value was 0.11 (at 226 Hz) and the highest ambient pressure absorbance value was 0.84 (at 1000 Hz). The lowest pre-operative ambient pressure absorbance value recorded in the study group was 0.14 (at 226 Hz) and the highest pre-operative ambient pressure absorbance value in this group was 0.62 (at 1000 Hz). One month after surgery, the lowest ambient pressure absorbance value was 0.07 (at 5822 Hz) and the highest ambient pressure absorbance value was 0.53 (at 1000 and 2000 Hz). Three months after surgery, the lowest ambient pressure absorbance value was 0.05 (at 4000 Hz) and the highest ambient pressure absorbance value was 0.58 (at 1000 and 1587 Hz).

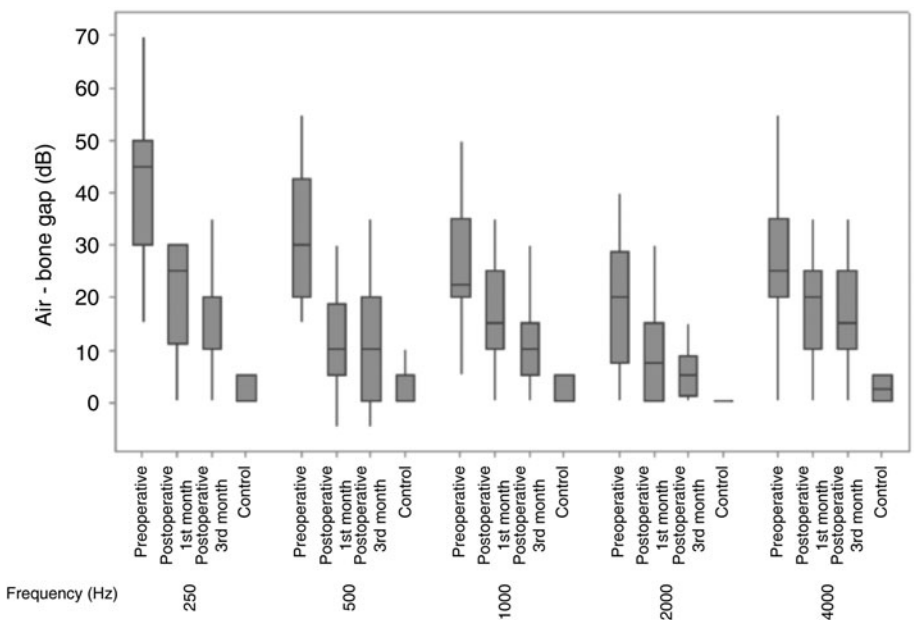

Figure 2. The air–bone gaps of the study and control groups.

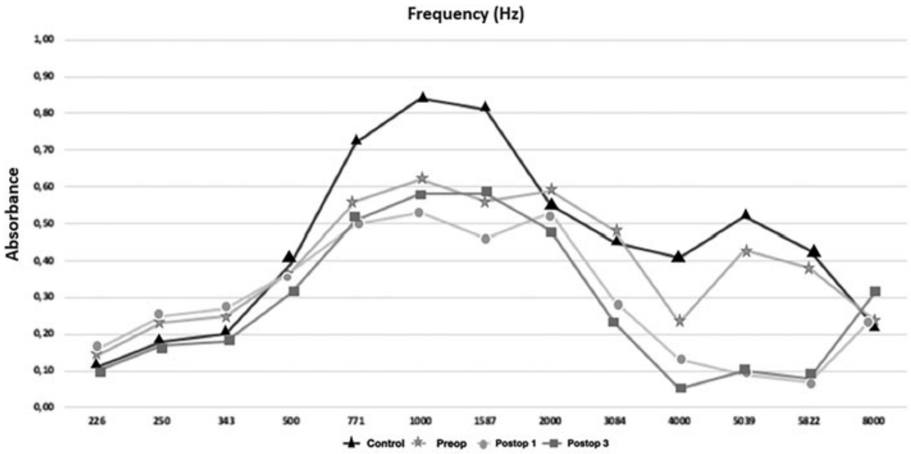

Figure 3. Frequency-specific absorbance values of the study and control groups at ambient pressure.

Comparative analysis of pre-operative absorbance (study group vs control group)

The pre-operative ambient pressure absorbance values of the study group were statistically significantly lower than those of the control group at 771, 1000, 1587 and 4000 Hz ($p < 0.05$) (Figure 3 and Table 1). The study group members were further divided into two subgroups: those with subtotal tympanic membrane perforations and those with central tympanic membrane perforations. When the pre-operative ambient pressure absorbance values recorded between 226 and 8000 Hz were compared between the subtotal and central tympanic membrane perforation subgroups, no significant differences were found ($p > 0.05$ for all frequencies).

Comparative analysis of post-operative absorbance (study group vs control group)

When the 3-month post-operative ambient pressure absorbance values of the study group were compared with the ambient pressure absorbance values of the control group, the values were found to be statistically similar at low frequencies; however, at middle and high frequencies, starting from 771 Hz, the values were significantly lower in the study group, except at 2000 and 8000 Hz ($p < 0.05$). A comparison of the 1-month post-operative ambient pressure absorbance values of the study group and the ambient pressure absorbance values of the control group showed that there were similarities at low frequencies, including at 3084 Hz; however, the ambient pressure absorbance values of the study group were lower at middle and high frequencies. These findings are similar to those observed three months after surgery (Figure 3 and Table 1).

The ambient pressure absorbance values of the study group members were assessed according to the origin of the graft cartilage. The ambient pressure absorbance values of the cavum concha, cymba concha and tragus cartilage subgroups were examined between 226 and 8000 Hz. No statistically significant differences were observed among the subgroups ($p > 0.05$ for all).

Intra-group absorbance changes in the study group

When the intra-group ambient pressure absorbance changes in the study group were examined, it was found that the pre-operative ambient pressure absorbance values at 3084, 4000, 5039 and 5822 Hz were higher than the 3-month post-operative ambient pressure absorbance values. The 1- and 3-month post-operative ambient pressure absorbance values were similar; however, the 3-month post-operative ambient pressure absorbance value was higher than the 1-month post-operative value at 1587 Hz. In addition, the ambient pressure absorbance values at 3084 Hz decreased over time (Figure 3 and Table 1).

Relationship between absorbance values and the air–bone gap

In this study, absorbance and the ABG were measured at ambient pressure in both groups. While the pre-operative and 1- and 3-month post-operative ambient pressure absorbance values recorded at 1000 and 4000 Hz showed significant negative correlations with the ABG values, all other correlation coefficients were not statistically significant (Table 2).

Discussion

The results of this study indicated that although the hearing thresholds of the patients improved significantly after type 1 cartilage tympanoplasty as measured with pure tone audiometry, they did not reach the normal thresholds of the controls. Three months after surgery, the wideband tympanometry results showed that the ambient pressure absorbance values of the patients were similar to those of the controls at low frequencies (226–500 Hz); however, lower ambient pressure absorbance values were obtained at middle and high frequencies, except at 2000 and 8000 Hz. The ABG and ambient pressure absorbance values were significantly negatively correlated at 1000 and 4000 Hz both pre- and post-operatively.

The anatomical success rates of temporal fascia grafts vary between 59.3 and 93.3 per cent, while this rate has been reported as 85–100 per cent for cartilage grafts.[4–8] In our study, the rate of anatomical success, which was defined as post-operative complete closure of the tympanic membrane perforation, was 90.9 per cent 3 months after surgery.

When hearing gain was examined by considering the pre- and post-operative PTAs of the study group, a hearing gain of 17.60 ± 8.48 dB was observed. The results indicate that the mean ABG of the study group decreased from 25.88 ± 9.31 dB pre-operatively to 10.88 ± 5.66 dB 3 months post-operatively, with a 15.0 ± 10.59 dB gain in the ABG. In terms of hearing gain, in line with the literature, our results confirm that type 1 cartilage tympanoplasty results in

Table 1. Comparison of absorbance values of the groups

		Groups				Inter-group statistics		Model statistics		
		Study		Control						
Frequency (Hz)	Time of measurement	$\bar{x}$	*ss*	$\bar{x}$	*ss*	*F*	*p*	Source of effect	*F*	*p*
226	Pre-operative	0.14	0.24	0.11	0.08	0.265	0.610	Group	0.399	0.531
	Post-operative first month	0.16	0.23			0.663	0.420	Time	0.952	0.395
	Post-operative third month	0.10	0.08			0.499	0.484	Group × time	0.952	0.395
	Intra-group statistics	$F = 1.903$, $p = 0.163$		$F = 0.000$, $p = 1.000$						
250	Pre-operative	0.23	0.24	0.18	0.09	0.691	0.411	Group	0.863	0.359
	Post-operative first month	0.25	0.23			1.215	0.277	Time	1.560	0.224
	Post-operative third month	0.17	0.09			0.376	0.543	Group × time	1.560	0.224
	Intra-group statistics	$F = 3.120$, $p = 0.056$		$F = 0.000$, $p = 1.000$						
343	Pre-operative	0.25	0.27	0.20	0.12	0.591	0.447	Group	0.820	0.371
	Post-operative first month	0.27	0.23			1.299	0.262	Time	1.539	0.228
	Post-operative third month	0.18	0.09			0.182	0.672	Group × time	1.539	0.228
	Intra-group statistics	$F = 3.078$, $p = 0.058$		$F = 0.000$, $p = 1.000$						
500	Pre-operative	0.37	0.21	0.39	0.16	0.039	0.844	Group	0.404	0.529
	Post-operative first month	0.37	0.26			0.035	0.853	Time	0.601	0.553
	Post-operative third month	0.31	0.14			1.865	0.180	Group × time	0.601	0.553
	Intra-group statistics	$F = 1.202$, $p = 0.312$		$F = 0.000$, $p = 1.000$						
771	Pre-operative	0.56	0.24	0.72	0.18	**5.489**	**0.024**	Group	**11.900**	**0.001**
	Post-operative first month	0.50	0.23			**11.014**	**0.002**	Time	0.564	0.574
	Post-operative third month	0.51	0.21			**11.095**	**0.002**	Group × time	0.564	0.574
	Intra-group statistics	$F = 1.128$, $p = 0.335$		$F = 0.000$, $p = 1.000$						
1000	Pre-operative	0.62	0.24	0.84	0.14	**13.905**	**0.001**	Group	**27.927**	**<0.001**
	Post-operative first month	0.53	0.23			**27.379**	**<0.001**	Time	1.664	0.203
	Post-operative third month	0.58	0.21			**22.612**	**<0.001**	Group × time	1.664	0.203
	Intra-group statistics	$F = 3.127$, $p = 0.067$		$F = 0.000$, $p = 1.000$						
1587	Pre-operative	0.56[*,†]	0.26	0.81	0.15	**14.138**	**0.001**	Group	**27.653**	**<0.001**
	Post-operative first month	0.46[*]	0.21			**37.145**	**<0.001**	Time	**3.256**	**0.049**
	Post-operative third month	0.58[†]	0.24			**12.908**	**0.001**	Group × time	**3.256**	**0.049**
	Intra-group statistics	$F =$ **6.511**, $p =$ **0.004**		$F = 0.000$, $p = 1.000$						
2000	Pre-operative	0.59	0.25	0.55	0.26	0.287	0.595	Group	0.058	0.811
	Post-operative first month	0.53	0.21			0.086	0.771	Time	1.100	0.343

(*Continued*)

Table 1. (*Continued.*)

		Groups				Inter-group statistics		Model statistics		
		Study		Control						
Frequency (Hz)	Time of measurement	$\bar{x}$	*ss*	$\bar{x}$	*ss*	*F*	*p*	Source of effect	*F*	*p*
	Post-operative third month	0.48	0.29			0.678	0.416	Group × time	1.100	0.343
	Intra-group statistics	*F* = 2.201, *p* = 0.125		*F* = 0.000, *p* = 1.000						
3084	Pre-operative	0.48*	0.21	0.45	0.28	0.130	0.721	Group	**3.939**	**0.046**
	Post-operative first month	0.29†	0.23			3.473	0.061	Time	**13.396**	**<0.001**
	Post-operative third month	0.23‡	0.12			**10.602**	**0.002**	Group × time	**13.396**	**<0.001**
	Intra-group statistics	*F* = **26.791**, *p* < **0.001**		*F* = 0.000, *p* = 1.000						
4000	Pre-operative	0.23*	0.26	0.41	0.31	**4.001**	**0.053**	Group	**13.642**	**0.001**
	Post-operative first month	0.13*,†	0.22			**10.902**	**0.002**	Time	**3.860**	**0.030**
	Post-operative third month	0.05*	0.07			**25.359**	**<0.001**	Group × time	**3.860**	**0.030**
	Intra-group statistics	*F* = 7.721, *p* = **0.002**		*F* = 0.000, *p* = 1.000						
5039	Pre-operative	0.43*	0.32	0.52	0.24	1.009	0.322	Group	**28.112**	**<0.001**
	Post-operative first month	0.09†	0.09			**54.430**	**<0.001**	Time	**10.047**	**<0.001**
	Post-operative third month	0.10†	0.08			**55.342**	**<0.001**	Group × time	**10.047**	**<0.001**
	Intra-group statistics	*F* = 20.094, *p* < **0.001**		*F* = 0.000, *p* = 1.000						
5822	Pre-operative	0.38*	0.32	0.43	0.21	0.415	0.523	Group	**20.174**	**<0.001**
	Post-operative first month	0.07†	0.11			**45.254**	**<0.001**	Time	**8.909**	**0.001**
	Post-operative third month	0.08†	0.14			**37.006**	**<0.001**	Group × time	**8.909**	**0.001**
	Intra-group statistics	*F* = **17.818**, *p* < **0.001**		*F* = 0.000, *p* = 1.000						
8000	Pre-operative	0.24	0.22	0.22	0.14	0.104	0.749	Group	0.500	0.484
	Post-operative first month	0.25	0.25			0.148	0.702	Time	0.544	0.585
	Post-operative third month	0.31	0.32			1.121	0.296	Group × time	0.544	0.585
	Intra-group statistics	*F* = 1.089, *p* = 0.347		*F* = 0.000, *p* = 1.000						

*, † and ‡ indicate intra-group differences. Groups with the same symbol are statistically similar. Bold font indicate statistical significance (p<0.05).

significant hearing gain; however, the hearing of these patients cannot reach that of healthy people.[5,9,10]

Wideband tympanometry is based on the same working principle as conventional tympanometry, yet it is more sensitive and provides more detailed information than conventional tympanometry for middle-ear conditions and conductive hearing loss. This is because wideband tympanometry utilises click stimuli to collect information across a wide frequency range. However, examining and interpreting the absorbance values recorded at all 107 frequencies via wideband tympanometry is difficult, therefore, for convenience, it is important to know the normative data values at certain frequencies.

In this study, ambient pressure absorbance values at 226, 250, 500, 771, 1000, 1587, 2000, 3084, 4000, 5039, 5822 and 8000 Hz were analysed. We focused on the ambient pressure absorbance values obtained at 250, 500, 1000, 2000, 4000 and 8000 Hz to correlate the wideband tympanometry results with the pure tone audiometry results, and to compare our results with those of similar previous studies.

The studies that have defined the use of wideband absorbance have indicated that absorbance values differ as a function of frequency and that absorbance reaches a maximum at 1000–4000 Hz then decreases at frequencies lower than 1000 Hz and higher than 4000 Hz.[11,12] When we examined

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Table 2. The relationship between absorbance values and air–bone gap frequency

	Air–bone gap (Hz)									
	250		500		1000		2000		4000	
Absorbance	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Pre-operative	−0.051	0.754	−0.122	0.452	**−0.557**	**<0.001**	0.035	0.829	**−0.335**	**0.035**
Post-operative first month	0.091	0.574	0.006	0.972	**−0.599**	**<0.001**	−0.134	0.410	**−0.421**	**0.007**
Post-operative third month	−0.161	0.322	−0.071	0.665	**−0.425**	**0.006**	−0.005	0.974	**−0.467**	**0.002**

r = Pearson correlation coefficient

the absorbance values of the healthy control group, we observed that the absorbance increased from 226 to 1000 Hz, peaked at 1000 Hz, decreased to 4000 Hz, rose again at 5039 Hz and decreased to 8000 Hz. Others have reported similar findings: an absorbance notch at 4000–5339 Hz and another peak at a higher frequency.[13,14]

A study that analysed the results of wideband reflectance of otosclerotic ears before and approximately one month after surgery reported that a significant change in the reflectance pattern may be a useful objective tool for monitoring the effect of reconstructive stapes surgery.[15] In that study, a non-pressurised measurement method was preferred to protect the middle-ear structures during the post-operative period. The capacity to take measurements under non-pressurised conditions is one of the striking advantages of wideband tympanometry; it is not possible in conventional tympanometry. Hence, we utilised wideband tympanometry to take measurements under non-pressurised conditions to evaluate the tympanic membrane and middle-ear functions without damaging the middle-ear structures during the early post-operative period.

The pre-operative absorbance values of the study group (i.e. patients with perforated tympanic membranes) were similar to those of the control group at low frequencies (226–500 Hz), and the most significant declines were observed at 771, 1000, 1587 and 4000 Hz. In a study that investigated the absorbance characteristics of perforated eardrums, it was reported that the pre-operative absorbance values of individuals who were scheduled to undergo tympanoplasty were similar to those of control group individuals at low frequencies; however, the absorbance values of the individuals with perforated eardrums were significantly lower at 800 Hz and higher frequencies.[16] Our findings align with these results. In addition, a review reported that ears with perforated eardrums exhibited greater absorbance at low frequencies and, interestingly, that smaller perforations had greater effects on absorbance.[14]

Voss *et al.* examined the effects of middle-ear diseases on reflectance and found that tympanic membrane perforation caused a decrease in reflectance (increase in absorbance) at low frequencies and that as the perforation size increased, the reflectance steadily increased toward the normal values at low frequencies.[17]

It is worth noting that the absorbance values at some frequencies have been shown to vary in studies that have examined the effect of perforated ears. This is because the middle-ear mechanics are affected in various ways by the perforation site and size. In our study, the patients with perforated tympanic membranes were divided into two subgroups (subtotal and central perforations), according to the extension of the perforation to the tympanic annulus, and the absorbance values of these two subgroups were similar. One of the limitations of our study is that we did not strictly determine the location and size of the tympanic membrane perforations.

Özdamar *et al.* suggested that using the 226 Hz probe tone was not sufficient for fully evaluating the rigidity of the tympanic membrane and ossicular chain, and that the use of high-frequency tympanometry, particularly in cases of cartilage tympanoplasty, would provide better results due to the thickness and hardness of the cartilage.[9]

In our study, which is the first to investigate the early post-operative absorbance after cartilage tympanoplasty, post-operative absorbance was evaluated within the first 3 months after surgery, and although the absorbance values were lower at middle and high frequencies (except 2000 and 8000 Hz) compared to those of normal individuals, the patients who underwent cartilage tympanoplasty had similar absorbance values to the controls at low frequencies. In other studies, the post-operative absorbance values of patients who underwent tympanic membrane grafting with fascia in type 1 tympanoplasty were similar to those of a control group at low frequencies; however, their absorbance values were lower than those of the control group at middle and high frequencies.[16,18]

Our findings are generally consistent with those findings in terms of absorbance configuration, and the stiffness of the repaired tympanic membrane resulted in less absorbance. In another study, the absorbance values of a cartilage tympanoplasty group were lower than those of normal individuals at all frequencies.[19] When the values obtained in that study were compared with the early post-operative results of our study, inconsistencies were noted, and this is likely due to the fact that the post-operative wideband tympanometry measurements were taken over a broad period, between 12 and 120 months, in that study.[19]

In our study, the absorbance values of the study group were also comparatively examined according to the harvesting site of the grafted cartilage: the cavum concha, cymba concha and tragus. Yüksel Aslıer *et al.* studied two types of grafts, tragal and conchal, and reported that patients who received tragal cartilage had higher ambient pressure absorbance values at 2000 and 2828 Hz than patients who received conchal cartilage.[19] Zahnert *et al.* examined the frequency response functions of tragal and conchal cartilage plates using a laser Doppler interferometer and found no statistical difference in the acoustic transfer properties of these cartilage types.[20] In our study, however, we did not find any statistically significant differences among the three cartilage types. Further studies with larger populations are required to determine the differences in outcomes that can be attributed to the use of different types of graft cartilage.

When the post-operative changes in the study group were examined, the one- and three-month post-operative absorbance values were found to be generally similar. Although the absorbance values showed some differences at some frequencies between the first and third post-operative months, we concluded that these differences were not important because there was a limited time interval between the two measurements. Park *et al.* stated that there was a decrease in absorbance 6 months after surgery compared with the pre-operative period and that even though a slight increase was observed 12 months after surgery, the absorbance values were still not within the normal limits.[16] Studies with longer follow-up periods will contribute important information to the literature in terms of the changes in the mass and stiffness of repaired tympanic membranes and the effects on hearing.

In this study, ABG values were used to exclude the effects of sensorineural hearing loss, and their relationship with absorbance values was examined. A statistically significant negative correlation was found between ABG and absorbance values at 1000 and 4000 Hz in the pre- and post-operative periods (first and third months). Other correlation coefficients were not statistically significant.

In the study by Yüksel Aslıer *et al.*, a comparative frequency-specific analysis between ambient pressure absorbance and ABG indicated that the only significant relationship was a negative correlation at 1000 Hz.[19] Park *et al.* did not find any correlation between absorbance and ABG, but they found a significant correlation at 1000 Hz in the post-operative period.[16] In our study, the highest ambient pressure absorbance values in the control group (and in the study group) were recorded at around 1000 Hz and decreased toward lower and higher frequencies. This finding is consistent with the fact that the greatest pressure gain occurs around 1000–2000 Hz in humans.[21,22] It also clearly demonstrates that wideband tympanometry is a clinically reliable tool for studying absorbance changes in repaired tympanic membranes.

Because a non-pressurised method was used in this study during the early post-operative period, the absorbance values at the tympanometric peak pressure could not be obtained, and resonance frequency values that can be obtained with a pressurised method could not be estimated. However, when we compared the study and the control groups, we concluded that while the absorbance was low at middle and high frequencies, similar absorbances were recorded at 2000 Hz and the resonance frequency increased at 2000 Hz as a result of the stiffness effect of the cartilage graft, therefore a notch was observed at 2000 Hz. Thus, the reason for there being no correlation between the groups at 2000 Hz but correlation at 1000 and 4000 Hz was the effect of there being similar absorbances at 2000 Hz. Because measurements can be taken at tympanometric peak pressure without damaging the graft at later time points than those used in this study, future studies with longer follow-up periods should be conducted and include measurement of the resonance frequency at tympanometric peak pressure.

- The success rate of cartilage graft tympanoplasty, which is often preferred because of its durability and high success rates, was found to be 90.9 per cent
- Conducting post-tympanoplasty audiological testing is vital for both post-operative and auditory recovery
- The negative correlation found between the air–bone gap and ambient pressure absorbance values shows that it may be useful to include wideband tympanometry in the routine audiological test protocol and as a crossover test
- Conducting studies that have longer follow-up periods and that compare different graft types will contribute to the advancement of this field

Similar absorbance values were also obtained at the high frequency of 8000 Hz. In the literature, it has been mentioned that systems used to measure absorbance may be unreliable at frequencies above 4000 Hz.[18] There are also different interpretations in the literature of the meaning of absorbance values at the highest frequencies.[16,19]

Conclusion

This is the first study to analyse absorbance before type 1 cartilage tympanoplasty and in the early post-operative period using wideband tympanometry. Statistically significant differences were found between the ambient pressure absorbance values of patients who underwent a tympanic membrane cartilage graft and healthy controls. It was determined that the major differences were at middle and high frequencies.

Statistically significant negative correlations were found between ABG and ambient pressure absorbance values at 1000 and 4000 Hz. Given this relationship between ABG and ambient pressure absorbance, it is vital to use two testing methods and cross-test controls to increase the clinical utility of wideband tympanometry.

Based on our findings, wideband tympanometry has potential as an objective, rapid and reliable tool for monitoring post-operative changes in repaired tympanic membranes and understanding how closely reconstructed tympanic membranes resemble normal tympanic membranes. Our findings have implications for future studies on tympanic membrane reconstruction and provide important contributions to the literature. Further studies with larger populations are needed to generate ambient pressure absorbance normative data for normal and abnormal tympanic membranes.

Competing interests. None declared

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