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Original Article

Effect of cartilage tympanoplasty operation on compliance and hearing results

Kartilaj timpanoplasti operasyonunun komplians ve işitme sonuçları üzerine etkisi

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ABSTRACT

Aim: The purpose of this study was to investigate the effect of cartilage island grafts used in type 1 tympanoplasty surgery on compliance and hearing results.
Methods: In this retrospective study, the medical records of patients who underwent type 1 tympanoplasty between May 2019 and December 2021 were reviewed. A total of 40 patients were included in the study. Preoperative audiological and tympanometry test results were compared with 6-month postoperative results. The effect of cartilage island graft on compliance and hearing levels was compared, preoperatively and postoperatively at the 6th-month follow-up.
Results: Forty percent of patients were male, and 60% were female (n=24). The mean age of patients was 41,2±12.5 years. All postoperative tympanometry results showed a type B tympanogram tracing, as a result, no compliance was detected. At 500 Hz-4000 Hz frequencies, both air conduction hearing levels and air-bone gap thresholds showed a statistically significant improvement ($p<0.001$). Speech recognition threshold also increased after surgery ($p<0.001$). However, there was no statistically significant change ($p>0.01$) in Speech discrimination rate.
Conclusion: Cartilage island grafts could be considered an appropriate surgical option for type 1 tympanoplasty because it leads to a significant gain in terms of hearing outcomes. The correction effects on both hearing levels and speech recognition thresholds were statistically significant in our results. No better compliance result was observed, all tympanometry tracing results showed a type B tympanogram after type 1 tympanoplasty with island cartilage graft. This result may indicate a decreased elasticity in the tympano ossicular chain by cartilage island grafting.

Keywords: Cartilage graft, compliance, hearing, tympanoplasty

ÖZ

Amaç: Tip 1 Timpanoplasti ameliyatı yapılan hastalarda, onarımda kullanılan kartilaj ada greftinin, postoperatif komplians ve işitme sonuçlarına etkisinin araştırılması.
Yöntem: Çalışmamızda Mayıs 2019-Aralık 2021 yılları arasında Tip 1 timpanoplasti operasyonu yapılan 40 hastanın kayıtları retrospektif olarak incelendi. Çalışmaya greft materyali olarak tragal kıkırdak kullanılan hastalar dahil edildi. Kıkırdak greftin komplians üstüne etkisi timpanometrik test bataryası kullanılarak, işitme üzerine etkileri de odyolojik test bataryası kullanılarak incelendi. Hastaların preopratif ve postoperatif 6. ay kontrollerinde yapılan odyolojik+timpanometrik batarya tetkikleri karşılaştırıldı.
Bulgular: Çalışmada incelenen 40 hastanın %40'ı erkek, %60'ı (n=24) kadındı, hastaların yaş ortalaması 41.2±12.5 idi. Yapılan timpanometrik tetkiklerde, tüm hastalarda tip B timpanogram eğrisi elde edildi. Karşılaştırılan preoperatif ve postoperatif odyometrik tetkiklerde, 500 Hz-4000 Hz eşiklerindeki hava-kemik gaplerinin her biri ameliyattan sonra anlamlı derecede iyileşme göstermiştir ($p<0.001$). Ayrıca preop 500-4000 Hz ortalamasındaki hava-kemik gapi de ameliyat sonrası anlamlı olarak iyileşme göstermiştir ($p<0.001$). Konuşmayı alma eşiği değerlerinde ve postoperatif eşiklerde istatistiksel olarak anlamlı iyileşme gözlendi ($p<0.001$). Konuşmayı ayırt etme skorlarında ise postoperatif anlamlı bir değişim gözlenmedi ($p>0.01$).

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Sonuç: Tragal ada kartilaj grefti, hem işitme eşiklerini düzelten hem de konuşmayı anlama eşiklerini iyileştiren bir greft materyali olarak Tip 1 timpanoplasti ameliyatlarında güvenle tercih edilebilecek bir greft materyali olarak değerlendirildi. Timpanometri testlerinde elde edilen Tip B timpanogram eğrisi, kullanılan ada kartilaj greft materyalinin timpanik membran-osiküler zincir sistemi esnekliğini azalttığına dikkat çekmiştir.

Anahtar kelimeler: Timpanoplasti, komplians, kartilaj greft, işitme

INTRODUCTION

Tympanoplasty is a surgical technique used for the repair of tympanic membrane perforation and the aim of the surgery is to improve hearing by eradicating middle ear diseases. There are five types of tympanoplasty surgery described by Wullstein and Zollner (1). The subject of our study is type 1 tympanoplasty, which only targets the tympanic membrane perforation without ossicular chain repair. Since tympanoplasty was defined, many different tissues, such as temporal muscle fascia, perichondrium, periosteum, cartilage, dura mater, adipose tissue, and vein tissue, have been used as grafting materials in membrane reconstruction over time. Temporal muscle fascia is the most frequently preferred material among these grafts; however, cartilage grafting has become more popular in recent years due to the fact that the cartilage tissue is resistant to retraction, the success rate of graft adherence is observed as 82%-100% (2,3), and it can preserve its shape and structure for a long time without being infected (4).

Evaluation of hearing and performing diagnostic tests constitute the beginning of the clinical decision-making process in otology. The audiological test battery is essential in determining the level and severity of hearing loss. Acoustic immittance (tympanometry test battery) provides information about the auditory functions of the middle ear. Air conduction and bone conduction thresholds are determined by pure tone audiometry. Speech tests included in the audiological test battery provide information on speech recognition threshold (SRT), speech discrimination rate (SDR) in the differential diagnosis of hearing loss, and a person's effective communication skills. Pure tone audiometry also plays an important role in making surgical decisions and identifying conditions that require rehabilitation (5). Tympanometry objectively evaluates the compliance between the tympanic membrane and the ossicular chain. The measurement of acoustic energy reflected from the tympanic membrane provides information about the conduction characteristics in the middle ear. The magnitude of reflected acoustic energy varies with middle ear function and tympanic membrane status (hardness, thickness, retraction, perforation, etc.). When the strength of reflected energy increases, the conductive hearing system is less compliant (5). Static compliance is a value of the elasticity of the middle ear and associated structures, measured by tympanometry. Tympanometry measurements provide curves that can be simply classified as type A, type B, Type C. In the type A tympanogram, the peak pressure is in the range of -100/+100 daPa, expressing normal middle ear pressure. In type B, although there is no obvious peak, the obtained flat represents the absence of compliance and reflects the presence of otitis media with effusion, space-occupying lesion in the middle ear cavity, or perforation of the tympanic membrane. In type C, the peak pressure is greater than -100 daPa, indicating eustachian tube dysfunction.

To our knowledge, the effect of cartilage graft on compliance has not been investigated before in the English literature. For this reason, our purpose is to investigate the effect of cartilage island graft on compliance and hearing levels in patients who underwent Type 1 tympanoplasty.

MATERIALS

Our study is a retrospective study in which 40 patients (total of 40 ears) who underwent Type 1 tympanoplasty using tragal cartilage for cartilage island graft material (the thickness of which is lower than 1mm, tragal cartilage was used in partial thickness) in Ankara City Hospital Otorhinolaryngology Department between May 2019 and December 2021 were examined. All surgeries were performed with the same technique and by the same surgical group. The ethics committee approval was received from Ankara City Hospital, Number 1 Clinical Research Ethics Committee, dated 21.09.2022 and numbered E1-22-2926. While including patients, no gender discrimination was observed. Patients with central tympanic membrane perforation (at least 50% of tympanic membrane surface perforation) were detected by preoperative otoscopic examination. Patients with available data for at least 6 months postoperatively were included in our study. Patients with successful graft results (no perforation, retraction, lateralization, or graft granulation in the applied graft) were included. Patients with marginal perforation, ossicular chain defects, cholesteatoma, otorrhea, middle ear granulation, previous middle ear surgery, and tympanosclerosis were excluded from the study. The patient's audiology and tympanometry test results were evaluated preoperatively and postoperatively. Preoperative and postoperative pure tone averages, changes in air-bone gaps, SRT, SDR, and compliance values from tympanometry were evaluated. All surgical procedures were performed by the same surgical team with a postauricular approach. Tragal cartilage graft was used in all patients. Patients were followed up regularly in the ENT clinic at the 1st, 3rd, and 6th months. At the sixth-month evaluation, audiometric and tympanometric tests were repeated. In each audiogram, the mean air-bone gap was calculated and evaluated at 500, 1000, 2000, and 4000 Hz. Speech recognition threshold and speech discrimination rate were determined. Compliance was assessed by tympanometry. Pre- and postoperative results were compared using the Wilcoxon signed ranked test. Statistical analysis was performed by using SPSS (SPSS 15.0 for Windows; SPSS Inc., Chicago, IL, 2001). Our study was carried out in accordance with the principles of the Declaration of Helsinki.

Table 1. Demographic features of the patients.

Demographics	Total
Sex n (%)	
Female	24 (%60)
Male	16 (%40)
Age	
Median (min; maks)	43 (18; 60)
Meant±SD	41.23±12.579

RESULTS

The mean age of the patients in the study was 41±12.5 years. Forty percent (n=16) of the patients were male and 60% (n=24) were female (Table 1). Type B tympanogram curves were obtained for 40 ears, and no postoperative compliance was observed in all patients.

Preoperative pure tone thresholds were considered separately as air and bone conduction, and the difference between them was calculated. The air-bone gaps at all the thresholds of 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz improved significantly after surgery (p<0.001) (Table 2). The preoperative air-bone gap (ABGAPPTA)

Table 2. Detailed analysis of preoperative and postoperative audiometric test results.

	Preop.		Postop.			Statistics	
	Median (min; max)	Mean±SD	Median (min; max)	Mean±SD	Change in median	z	p
ABGAP500	25 (5; 45)	28.38±11.00	15 (0; 40)	17.25±11.60	40%	5.043	<0.001
ABGAP1000	25(15; 45)	25.63±8.02	15 (0; 45)	15.88±9.86	40%	5.11	<0.001
ABGAP2000	25 (5; 45)	26.13±7.55	10 (0; 30)	12.13±8.97	60%	5.499	<0.001
ABGAP4000	20 (10; 45)	22.63±9.73	17.5 (0; 40)	17.13±10.97	12.5%	3.991	<0.001
ABGAPPTA	24.37 (12.5; 42.5)	25.68±7.06	13.75 (0; 37.5)	15.59±8.87	43.57%	5.515	<0.001
SRT	35 (25; 50)	36.75±6.15	15 (0; 35)	16.63±7.87	57.14%	5.533	<0.001
SD	88 (80; 100)	89.3±6.30	90 (80; 100)	90.30±5.79	2.27%	2.232	0.026

ABGAP500: Air bone gap at 500 Hz, ABGAP1000: Air bone gap at 1000 Hz, ABGAP200: Air bone gap at 2000 Hz, ABGAP4000: Air bone gap at 4000 Hz, ABGAPPTA: Air-bone gap at the mean of 500-1000-2000-4000 Hz, SRT: Speech recognition threshold, SD: Speech discrimination rate

at the mean of 500-1000-2000-4000 Hz showed statistically significant improvement postoperatively (p<0.001). The highest increase in the air-bone gap was observed at 2000 Hz (ABGAP), with a 60% improvement (Figure 1-2). The highest gain in ABGAP was observed at 2000 Hz with a 14 dB gain (Figure 3).

Postoperative thresholds showed a statistically significant (p<0.001) improvement in SRT values (Figure 4). On the other hand, no significant change was observed in SDR (p>0.01) (Figure 4).

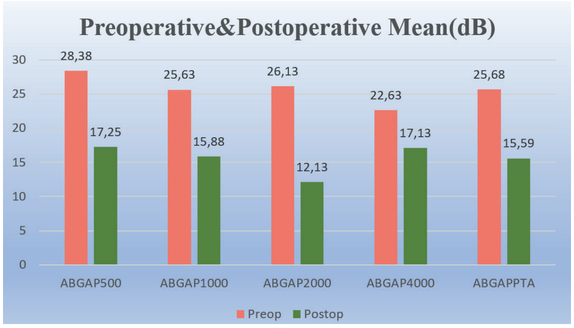

Figure 1. Change in frequency basis avarages of pre-post operative air-bone gap and pure tone avarage (ABGAP in dB).
ABGAP500: Air bone gap at 500 Hz, ABGAP1000: Air bone gap at 1000 Hz, ABGAP200: Air bone gap at 2000 Hz, ABGAP4000: Air bone gap at 4000 Hz, ABGAPPTA: Air-bone gap at the mean of 500-1000-2000-4000 Hz

Figure 2. Percentage recovery rates of frequency basis pre-post operative air-bone gap (ABGAP in dB).
ABGAP500: Air bone gap at 500 Hz, ABGAP1000: Air bone gap at 1000 Hz, ABGAP200: Air bone gap at 2000 Hz, ABGAP4000: Air bone gap at 4000 Hz

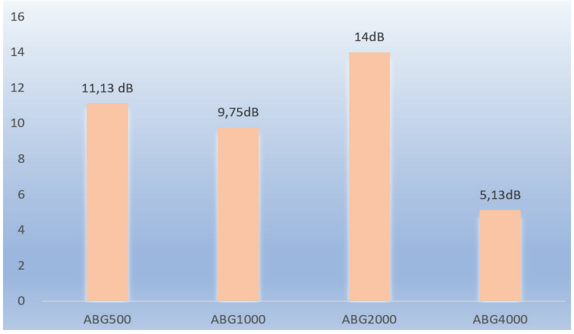

Figure 3. Frequency basis air bone gap (ABG) increase (dB).
ABGAP500: Air bone gap at 500 Hz, ABGAP1000: Air bone gap at 1000 Hz, ABGAP200: Air bone gap at 2000 Hz, ABGAP4000: Air bone gap at 4000 Hz

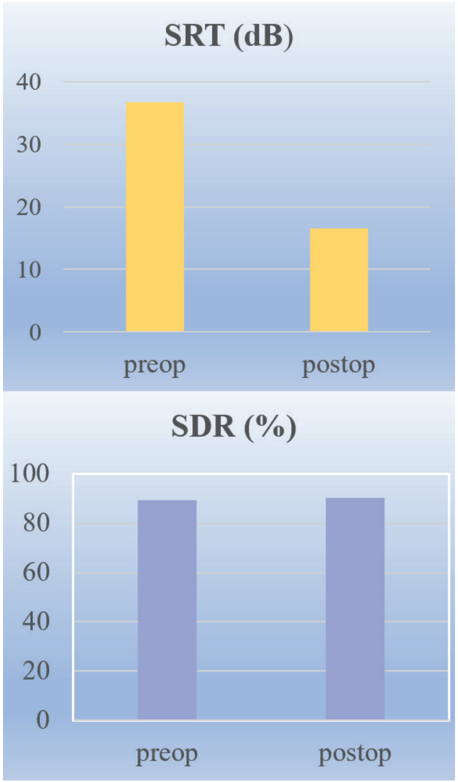

Figure 4. Pre-post operative speech recognition treshold (SRT) avarage (dB), and pre-post operative speech discrimination rate avarage (%).

DISCUSSION

Cartilage grafts are being discussed for being more suitable in tympanoplasty due to some physical properties they have. These grafts maintain their viability with blood diffusion, increase the success rate of the surgery, and also preserve their structure for a long time, resulting in being more resistant to retraction and infection (6). Therefore, we chose cartilage grafting in tympanoplasty and aimed to investigate its effect on compliance and hearing levels.

Murbe et al.[7] investigated the acoustic properties of different cartilage reconstruction techniques used in tympanoplasty, which were compared with a single-point Laser Doppler interferometric measurement method. It has been determined that as the thickness of the cartilage bases decreases, the resonance frequencies decrease, but the amplitude at the resonance frequencies increases. Their results suggest that it is appropriate to use thinned cartilage grafts as islands or palisades, to obtain better acoustic resonance. Rana et al.[8] measured and compared tragal and conchal cartilage grafts intraoperatively and suggested that the thickness of tragal cartilage was significantly less than the thickness of conchal cartilage, also suggesting that to achieve the maximum acoustic benefit, this knowledge saves lots of time in slicing calculations between surgeries. In our study, we selected tragal cartilage island graft, the thickness of which is less than 1mm, and our results correlatively showed a significant gain in air and bone hearing levels. According to Zahnert et al.[9] study, cartilage slices thinner than 500 μm resemble the eardrum in terms of acoustic properties. According to Parelkar et al.[10] study, full-thickness and partial-thickness tragal cartilage grafts showed similar improvement postoperatively. Based on our postoperative hearing results, we suggest that tragal cartilage grafts can be used without the need to change the graft thickness. As agreed, tympanoplasty with cartilage grafting restored the hearing levels.

One of the main goals of our study was to investigate how hearing levels on a frequency basis were affected postoperatively after cartilage island grafting. We focused on the main frequencies in hearing level (500, 1000, 2000 and 4000 Hz), and how they were changed postoperatively. We think that what makes our current study valuable is to reveal the frequency-based acoustic changes of Type 1 tympanoplasty with cartilage grafting. Our results presented that the air-bone gaps at all the thresholds of 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz improved significantly after surgery ($p<0.001$). The preoperative air-bone gap (ABGAPPTA) at the mean of 500-1000-2000-4000 Hz showed a statistically significant ($p<0.001$) improvement postoperatively. The highest air-bone gap increase was observed at 2000 Hz (ABGAP), with a 60% improvement. The highest gain in ABGAP was observed at 2000 Hz with a 14 dB gain. Jumaily et al.[11] evaluated audiometric results after type 1 cartilage grafting tympanoplasty and they showed a decrease in the air-bone gap similar to our results. In addition, we found a gain in SRT but not in SDR. We thought that no alteration in SDR was caused by the characteristic of conductive loss. In the presence of conductive loss, the SRT threshold may be affected due to hearing loss and may be improved postoperatively. On the other hand, with a suitable high dB, the SDR may remain unchanged when audiometry is performed, as expected. Jain et al.[12] compared the audiological outcome of temporalis fascia versus island cartilage graft in type 1 tympanoplasty and suggested that there was no significant difference in the postoperative air-bone gap gains. Correlatively, Gerber et al.[6] compared temporalis fascia graft and cartilage graft used in type 1 tympanoplasty with pre- and postoperative audiometric changes. Although no significant difference was found between the two groups in terms of the air-bone gap, the improvement of the average air-bone gap was 9.1 dB at 500 Hz, 10.5 dB at 1000 Hz, 14.1 dB at 2000 Hz, and 9.5 dB at 4000 Hz according to the pre-and postoperative results in the cartilage grafted group, similar to our results, improvements were observed at all frequencies in the air-bone gap. It was thought that this situation might be related to the characteristics of the grafts. We suggest that while a type A tympanogram curve is obtained in a normally functioning eardrum, the fact that type B tympanogram is obtained in all patients after our surgery can be shown as evidence of this. Because the use of cartilage graft in tympanoplasty will affect the mobility, mass and stiffness of the repaired membrane. Type B tympanogram curves obtained also indicate that the flexibility of the system between the tympanic membrane and the stapes is not sufficient, and this is due to the structural feature of the cartilage tissue. However, there is a significant improvement in acoustic transmission. Because there will be a difference between the vibration of the non-perforated surface, an expected loss of energy in the presence of perforation, sound transmission is adversely affected.

The effects of perforation on middle ear conduction according to frequencies were investigated in fresh cadavers by Voss et al. (13). They found that the loss due to perforation was greatest at low frequencies and almost zero at 2000 Hz. They stated that they investigated perforations smaller than a total of 50% and 2000 Hz is the frequency that is least affected by perforation, however, they also suggested that these findings might change in the case of perforations greater than 50%. Along with the tragal cartilage grafting in our study, the increase in stiffness of the tympanic membrane- ossicular chain-oval window system and the increase in the middle ear resonance frequency may have caused the maximum improvement in the air-bone gap at 2000 Hz. Because the resonance frequency of the middle ear is directly proportional to the stiffness and inversely proportional to the mass. For example, in the case of ossicular chain discontinuity stiffness decreases and increases in otosclerosis (14,15).

CONCLUSION

We found that tragal cartilage island graft used type 1 tympanoplasty results had a positive effect on hearing threshold and SRT but did not have a significant change in SDR. Obtaining a type B tympanogram curve in all patients was thought to have caused a reduction in the flexibility of the tympanic membrane and ossicular chain system. The maximum air-bone gap improvement is likely at 200 Hz, possibly due to an increase in stiffness.

Ethics Committee Approval: The study protocol was approved by the Ankara City Hospital, Number 1 Clinical Research Ethics Committee (21.09.2022 / E1-22-2926).

Conflict of Interest: The authors have declared that they have no conflict of interest.

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