Hearing performance after myringoplasty with full-thickness cartilage: A propensity score-matched cohort study

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Abstract

Objective: Hearing performance after myringoplasty with full-thickness tragal cartilage (FTTC) has been questioned because a considerable difference exists between the graft and natural tympanum. This study aimed to analyze the air-bone gap (ABG) trends before and after myringoplasty and its interaction with risk factors in the FTTC group; further, it compared postoperative ABG in the FTTC group to that in the temporalis fascia (TF) and partial-thickness tragal cartilage (PTTC) groups. Design: A retrospective cohort study Setting: Tertiary care University Hospital Methods: The general linear model repeated measures was used to analyze ABG trends in the FTTC group and its influencing factors. Non-parametric tests were used to compare ABGs in the FTTC group and the other two groups. Propensity score matching was done to balance baseline characteristics between the TF and FTTC group. Results: The mean postoperative ABG in the FTTC group was 12.17±6.58 dB, and 90.9% of the patients had a mean ABG within 20 dB, which improved significantly after surgery ($F(1,108)=38.707$, $P<.001$). The tympanic perforation size and malleus handle exposure status, which significantly affected the preoperative ABG, did not affect postoperative hearing ($P>.05$). In the FTTC group, the mean ABG was comparable to that in the other two groups ($P>.05$). For all except 250 Hz, a similar audiological performance was observed in the FTTC and PTTC groups; FTTC had a better performance at 250 Hz ($Z=-2.277$, $P=.023$). Conclusions: Good hearing performance was achieved after myringoplasty with FTTC, irrespective of the preoperative perforation size and malleus handle exposure status.

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Design: A retrospective cohort study

Setting: Tertiary care University Hospital

Methods: The general linear model repeated measures was used to analyze ABG trends in the FTTC group and its influencing factors. Non-parametric tests were used to compare ABGs in the FTTC group and the other two groups. Propensity score matching was done to balance baseline characteristics between the TF and FTTC group.

Results: The mean postoperative ABG in the FTTC group was 12.17±6.58 dB, and 90.9% of the patients had a mean ABG within 20 dB, which improved significantly after surgery ($F_{(1,108)}$=38.707, P <.001). The tympanic perforation size and malleus handle exposure status, which significantly affected the preoperative ABG, did not affect postoperative hearing (P >.05). In the FTTC group, the mean ABG was comparable to that in the other two groups (P >.05). For all except 250 Hz, a similar audiological performance was observed in the FTTC and PTTC groups; FTTC had a better performance at 250 Hz (Z=-2.277, P =.023).

Conclusions: Good hearing performance was achieved after myringoplasty with FTTC, irrespective of the preoperative perforation size and malleus handle exposure status.

Keywords: cartilage; hearing tests; linear models; myringoplasty; propensity score; retrospective studies

Key points:

- To compare the hearing performance between the two myringoplasties, microscopic and endoscopic, and between full-thickness- and partial-thickness tragal cartilage graft (FTTC and PTTC, respectively) in endoscopic myringoplasty.
- Hearing improvement was achieved irrespective of the preoperative tympanic perforation size and the malleus handle exposure status in the FTTC group.
- The postoperative air-bone gap was comparable in the temporalis fascia and PTTC groups
- The audiological improvement at 250 Hz was better in the FTTC group than in the PTTC group.
- Good hearing performance was achieved after myringoplasty with FTTC, irrespective of the preoperative perforation size and malleus handle exposure status.

Introduction

Endoscopic myringoplasty has gained popularity in recent years, as its use can help to achieve a clear surgical vision,[1] less postoperative pain, and a high success rate both in anatomy and function.[2] Full-thickness tragal cartilage (FTTC) is the grafting material of choice for endoscopic myringoplasty.[3,4] FTTC is easy to harvest and suitable for one-handed operations under the endoscope due to its hardness. However, there is a considerable difference in the thickness, stiffness, and elasticity between FTTC and the natural tympanic membrane. Many otologists doubt its postoperative hearing performance. Performing myringoplasty under the microscope with a temporalis fascia (TF) graft is the classic surgical approach. However, in endoscopic myringoplasty, partial-thickness tragal cartilage (PTTC) is used as a graft, which is closer to the natural tympanic membrane. Here, we aimed to compare the hearing performance between the two myringoplasties, microscopic and endoscopic, and between FTTC and PTTC graft in endoscopic myringoplasty. We also compared the postoperative audiological performance between them.

Materials and Methods

Subjects

This retrospective cohort study was conducted at the Department of Otolaryngology of a tertiary hospital in China between January 2017 and February 2020. Adult patients (>18 years) with chronic otitis media, persistent tympanic membrane perforation, an intact ossicular chain on computed tomography scan, and ossicular chain mobility during the intraoperative assessment were included. Hearing performance in microscopic and endoscopic myringoplasties, each using a different graft, was compared. For the FTTC group, cartilage with no thinning and perichondrium on one side was used; the myringoplasty was performed under the endoscope. For the TF group, traditional myringoplasty was performed under the microscope using TF as a graft. For the PTTC group, ultra-thin tragal cartilage was used and the myringoplasty was performed under the endoscope. Postoperative tympanum closure rate and hearing performance were evaluated 3 months after the operation.

The study protocol was approved by the Ethics Committee of the Hospital.

Definitions of variables

The mean air-bone gap (ABG) was the average ABG value at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz. The mean ABG was divided into four categories: 1) [?]10 dB, 2) 11–20 dB, 3) 21–30 dB, 4) [?]31 dB. Three factors affecting the ABG were included in this study: time (before and after surgery), tympanic perforation size (large [[?]50%] and small [<50%]), and exposure of malleus handle (exposed and unexposed).

Statistical analysis

Continuous variables were presented as mean +- standard deviation for normally distributed variables and as median (interquartile range) for variables that followed a non-parametric distribution. Categorical variables were compared using the chi-square test. Quantitative continuous variables were compared using the unpaired Student'st -test or the Mann-Whitney U test for normally and non-normally distributed variables, respectively. The factors affecting ABG were compared using the general linear model repeated measures test.

Propensity score matching (PSM) was performed to balance the baseline characteristics between the TF group and the FTTC group. Age, gender, size of perforation, exposure of malleus handle, and ABG values at frequencies from 250 Hz to 4000 Hz before surgery were matched. Before PSM, there were 40 patients in the microscopic group and 111 patients in the endoscopic group. However, after the cohorts were propensity score-matched to create a 1:1 matched set using a caliper width of 0.02; a total of 38 patients were included in each group. After the two groups were matched, the distribution of the ABG values for frequencies of 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz did not obey normal distribution; therefore, a non-parametric test, to compare two-related-samples, was used for analysis.

P -values $< .05$ was considered statistically significant. IBM SPSS for Windows version 22.0 (IBM Corp., Armonk, NY, USA) was used for analyses.

Myringoplasty procedure

After infiltration of the canal with local anesthesia, the edges of the perforation were freshened. A broad tympanomeatal flap was elevated from 11 to 6 o'clock (left ear) and the middle ear cavity was entered; care was taken to preserve the chorda tympani nerve. The ossicular chain was palpated and its mobility was confirmed. The tympanic mucosa, anterior space of malleus, anterior and posterior tympanic isthmus, and eustachian tube orifice were explored. FTTC was harvested with perichondrium on one side, and a "V" shaped notch was made. The epithelium on the malleus handle was removed, and the FTTC was inserted between the malleus handle and the tympanum, with the perichondrium facing outward. The "V" shape was embedded in the short process of the malleus. The graft was supported with gelatin sponges soaked in normal saline. A zero-degree endoscope (diameter, 3 mm; length, 140 mm) was used under an endoscope monitoring system (Storz TC200, Germany).

In the TF group, a classic microscopic myringoplasty was performed through postauricular and transcanal approaches utilizing the TF for reconstruction. The graft was placed under the malleus handle.

In the PTTC group, endoscopic myringoplasty was performed utilizing ultra-thin tragus cartilage with a perichondrium layer as the graft, which was placed under the malleus handle.[5]

Results

Myringoplasty with FTTC graft: Factors affecting the mean ABG and its trend

The average thickness of the FTTC was 0.850 +- 0.117 mm (range, 0.642–1.083 mm). The mean operation time was 52.44 +- 14.04 minutes, and the average postoperative dry ear time was 3.457 +- 1.78 weeks. The tympanic membrane integrity was restored in 91% of the cases. Figure 1 presents key images before, during, and after surgery. A mean ABG of 12.17 +- 6.58 dB was observed postoperatively ([?]10 dB, 45%; 11–20 dB, 45.9%; 21–30 dB, 7.2%; [?]31 dB, 1.8%; Figure 2A.)

Further, the impact of the factors affecting ABG was explored. The factors assessed before and after surgical intervention were perforation size and malleus handle exposure status. The mean ABG changed significantly

after surgical intervention ($F_{(1,108)} = 38.707$, $P < .001$). The tympanic perforation size and malleus handle exposure status significantly affected the mean preoperative ABG ($F_{(1,108)} = 5.969$, $P = .016$; $F_{(1,108)} = 7.281$, $P = .008$, respectively). Further, no interaction was found between surgical intervention and perforation size ($F_{(1,108)} = 1.022$, $P = .314$) and between surgical intervention and malleus handle exposure status ($F_{(1,108)} = 0.053$, $P = .818$). To summarize these findings, the perforation size and malleus handle exposure status did not affect the ABG trend (change in the ABG values before and after surgery). The distribution of mean ABG under different factors is presented in Figure 2B.

Comparison of audiological performance betweenTF and FTTC groups

3.2.1 Comparison of the baseline characteristics before and after PSM

Baseline characteristics (age, gender, perforation size, malleus handle exposure status, and ABG value for frequencies of 250 Hz to 4000 Hz before surgery) in the TF and FTTC groups were compared; a significant difference was observed in the ABG values at 2000 Hz. However, after PSM, the variables in the two groups were balanced. The differences in the baseline characteristics before and after surgery are shown in Supplementary Table.

3.2.2 Comparison of hearing performance in the two groups

The mean ABG values in the TF and FTTC group were 13.75 (8.75–16.25) dB and 10 (6.25–15) dB, respectively; no significant difference was observed in the mean ABG of the two groups (Z = -1.051, P = .293, Figure 3A.). Further, the ABGs at 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz in the two groups were compared; for each frequency, no significant difference was observed between the two groups (P> .05, Table 1).

3.3 Comparison of audiological performance between the FTTC and PTTC groups

First, baseline characteristics between the two groups were compared, and no statistically significant differences were observed (Table 2). The mean ABG values in the PTTC and FTTC groups were 12.5 (8.75–16.25) dB and 11.25 (6.25–15) dB, respectively, with no significant difference between the two groups (Z = -0.958, P = .338, Figure 3B.). At frequencies 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz, there was no significant difference in ABG values between the two groups (P> .05) (Table 3). The postoperative ABG in the FTTC group at 250 Hz was 15 (10–20) dB, which was better than that in the PTTC group (15 [15–20] dB, Z = -2.277, P = .023).

Discussion

Hearing improvement was achieved irrespective of the preoperative tympanic perforation size and malleus handle exposure status in the FTTC group. The postoperative ABG was comparable in the TF and PTTC groups. Moreover, the audiological improvement at 250 Hz was better in the FTTC group than in the PTTC group.

Endoscopic myringoplasty has received special attention in recent years. The grafts used in myringoplasty are diverse, such as temporalis muscle fascia,[6] tragus perichondrium,[7,8]tragus cartilage and perichondrium complex,[9] and porcine small intestine submucosa.[10] Minimal invasion and easy harvest, less postoperative pain, quicker postoperative recovery in anatomy and function, and strong ability to resist inflammation are the requirements of an ideal graft; since it meets the requirements, tragus cartilage is the material of choice. Moreover, it does not require an extra incision behind the ear, thereby avoiding long-term numbness [11] after the operation.

Endoscopic myringoplasty is a flexible and variable procedure as it facilitates multiple choices of grafts, varied graft placement, and different surgical approaches; however, on the downside, diversity may lead to discrepancies in postoperative hearing performance. There are three main cartilaginous grafts: perichondrium, full-thickness cartilage with perichondrium complex, and thinned cartilage with perichondrial complex. The commonly employed surgical approaches include the "put through"[12] method, which does not involve the elevation of the tympanomeatal flap, and the method involving the elevation of the tympanomeatal flap.

The location of graft placement also varies, such as incarceration on the tympanic membrane ("butterfly" method),[13] placed between the tympanic membrane and the malleus handle, or medial to the malleus handle. In this study, a broad tympanomeatal flap was lifted, and the FTTC was placed between the malleus handle and the tympanomeatal flap. In both traditional microscopic tympanoplasty with the TF and the FTTC surgery, a similar hearing performance was achieved after the surgery. In a meta-analysis[14] where different research groups adopted different surgical and graft placement strategies, a sub-analysis of prospective studies showed a lower mean postoperative ABG in patients using TF graft. The heterogeneity may have affected the stability of the results and led to the difference.

For all frequencies except 250 Hz, a similar audiological performance was observed in the FTTC and PTTC groups; FTTC had a better performance at 250 Hz. Similar comparisons were drawn in another study,[4] where no significant differences were observed in hearing improvement between the PTTC and the FTTC groups at 250 Hz, 500–2000 Hz, and 8000 Hz. Overall, our findings were in agreement, but PTTC had a better performance at 4000 Hz in the other study, whereas FTTC had a better performance at 250 Hz in our study. In the same study, the tensor tympani tendon was cut to make space in cases where the handle was foreshortened or medially displaced. This manipulation may have led to poor performance in the FTTC group at 250 Hz. The tensor tympani tendon cut did not affect hearing at 0.5 Hz–4 kHz after tympanoplasty,[15] but tensor tympani tendon contraction is related to low-frequency hearing loss.[16] In addition, barred cartilage, which might result in decreased tension of drum, was placed under the malleus, which may be responsible for the poor performance at 4000 Hz in the FTTC group in their study. In the future, the effect of tensor tympani tendon cut on low-frequency hearing can be explored.

Although reports on myringoplasty with FTTC graft have demonstrated good hearing performance, only a few articles have provided a convincing theoretical explanation. A study on biomechanical analysis[17] suggested the use of grafts with a thickness of 0.1–0.2 mm for medium-to-large perforations and <1.0 mm for small perforations, where the graft is a substitute for both mechanical stability and audibility. However, in this study, the thickness of the FTTC was 0.850 +- 0.117 mm, and good hearing results were obtained at each frequency. The middle ear can only provide about 20 dB of gain on average[18] and most of the gain comes from the area ratio of the tympanic membrane to the stapes. The air-containing middle ear cavity can reduce the sound pressure on the round window membrane.[19] Figure 1F shows that the graft fits well with the malleus handle; the new cartilage drum could provide a sufficient drum area and an aired cavity, so the graft would fit well and a good hearing performance with FTTC graft could be achieved. Moreover, a better hearing performance at 250 Hz was achieved in the FTTC group than that in the PTTC group. The possible reason for this could be that FTTC changes the stiffness of the tympanic membrane, which may be beneficial in low-frequency conductions. However, it does not mean that the FTTC graft can replace the PTTC graft, which is convenient for postoperative examination and manipulation.

Postoperative hearing performance in the FTTC group was independent of the preoperative tympanic perforation size and the exposure status of the malleus handle. According to our previous research, factors such as the state of mucosa and location of tympanic perforation do not affect the trends of ABG.[5]Another study also reported similar results.[20] In a previous study, a linear correlation was observed between the preoperative tympanum perforation size and postoperative ABG ($P = .0017$) at frequencies of 0.5 to 4 kHz, indicating an increased postoperative ABG in larger perforations; however, here, we specified only the P -values and did not provide the correlation coefficient or other parameters that reflect the relationship between the perforation size and postoperative ABG.

There are some limitations of this study. First, this was a retrospective analysis performed at a single center. Second, the sample size of the TF group was small, and the baseline characteristics between the TF and FTTC group were imbalanced. However, PSM was performed to resolve the issue of imbalanced baselines and sample sizes. Third, the follow-up duration of this study was short. The patients at this center came from all over the country. Since improvement in hearing and dry ear was observed in the early days after the surgery and a longer follow-up meant increased loss to follow-up, we chose 3 months as the endpoint of follow-up.

Conclusions

Good hearing performance at all frequencies was achieved in patients who underwent myringoplasty with FTTC graft, and these results were comparable to those of patients who underwent myringoplasty with TF and PTTC graft. The hearing performance was stable and independent of the preoperative tympanum perforation size and the exposure status of the malleus handle.

Conflict of Interest The authors declare that there is no conflict of interest.

Data Availability Statement The data that support the findings of this study are available on request from the corresponding authors. The data are not publicly available due to restrictions that they contain information that could compromise research participants' privacy.

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Tables

Supplementary Table The baseline before and after PSM in temporalis fascia and thick tragal cartilage groups

Variables	Variables	Before PSM TF	Before PSM FTTC	*P*	After PSM TF	After PSM FTTC	*P*
Age	Age	42(34.25~55)	48(34~58)	.231	43.289±14.268	42.684±11.727	.844
Gender	Male(%)	10(25)	40(36)	.204	10(26.3)	9(23.7)	1
	Female(%)	30(75)	71(64)		28(73.7)	29(76.3)	
Perforation size	[?]50% (%)	28(70)	89(80.2)	.186	27(71.1)	24(63.2)	.581
	<50% (%)	12(30)	22(19.8)		11(28.9)	14(36.8)	
Malleus	exposed	14(35)	46(41.4)	.475	13(34.2)	9(23.7)	.344
	unexposed	26(65)	65(58.6)		25(65.8)	29(76.3)	
BS_ABG250	BS_ABG250	30.00(20~35)	30.00(25~35)	.554	28.816±10.229	26.974±9.763	.561
BS_ABG500	BS_ABG500	25.00(16.25~30)	25.00(20~30)	.986	24.079±8.994	21.974±9.411	.465
BS_ABG1000	BS_ABG1000	20.00(15~25)	20.00(10~25)	.609	18.553±7.157	19.211±9.968	.299
BS_ABG2000	BS_ABG2000	15.00(10~20)	10.00(10~20)	.032	16.316±7.230	15.658±9.456	.291
BS_ABG4000	BS_ABG4000	20.00(15~25)	15.00(10~25)	.293	19.605±8.086	20.158±13.310	.908

TF: the temporalis fascia

FTTC: full-thickness tragal cartilage

Table 1. Comparison of ABG after surgery between the temporalis fascia and full-thickness tragal cartilage groups for each frequency

Frequency	**Group**	**ABG after surgery**	**Z value**	**P**
250Hz	TF	15(10~20)	-.270	.787
	FTTC	15(10~20)		
500Hz	TF	15(10~20)	-1.074	.283
	FTTC	10(10~16.25)		
1000Hz	TF	10(10~16.25)	-1.499	.134
	FTTC	10(5~15)		
2000Hz	TF	10(5~15)	-.999	.318
	FTTC	5(5~10)		

4000Hz	TF	10(5~20)	-.031	.975
	FTTC	10(5~21.25)		

TF: temporalis fascia

FTTC: full-thickness tragal cartilage

Table 2. The balanced baseline of the partial-thickness tragal cartilage and full-thickness tragal cartilage groups

Variables	**Variables**	**PTTC**	**FTTC**	**Z or χ^2**	**P**
Mean ABG before surgery	Mean ABG before surgery	17.5(12.5~22.5)	18.75(13.75~25)	-.996	.319
Age	Age	45(35.25~54)	48(34~58)		
Gender	Male(%)	45(35.7)	40(36)	.003	.959
	Female(%)	81(64.3)	71(64)		
Perforation size	[?]50% (%)	90(71.4)	89(80.2)	2.445	.118
	<50% (%)	36(28.6)	22(19.8)		
Malleus	Exposed	43(34.1)	46(41.4)	1.346	.246
	Unexposed	83(65.9)	65(58.6)		
BS_ABG250	BS_ABG250	27.5(20~35)	30(25~35)	-1.276	.202
BS_ABG500	BS_ABG500	22.5(15~30)	25(20~30)	-1.531	.126
BS_ABG1000	BS_ABG1000	15(10~25)	20(10~25)	-.231	.817
BS_ABG2000	BS_ABG2000	10(8.75~15)	10(10~20)	-.888	.375
BS_ABG4000	BS_ABG4000	15(10~25)	15(10~25)	-.599	.549

PTTC: partial-thickness tragal cartilage

FTTC: full-thickness tragal cartilage

Table 3. ABG after surgery between partial-thickness tragal cartilage and full-thickness tragal cartilage group

Frequency	Group	ABG after surgery	Z value	*P*
250Hz	PTTC	15(15~20)	-2.277	.023
	FTTC	15(10~20)		
500Hz	PTTC	15(10~15)	-.133	.894
	FTTC	15(10~20)		
1000Hz	PTTC	10(10~15)	-.952	.341
	FTTC	10(5~15)		
2000Hz	PTTC	10(5~10)	-1.030	.303
	FTTC	5(5~10)		
4000Hz	PTTC	15(8.75~20)	-.619	.536
	FTTC	10(5~20)		

PTTC : partial-thickness tragal cartilage

FTTC : full-thickness tragal cartilage

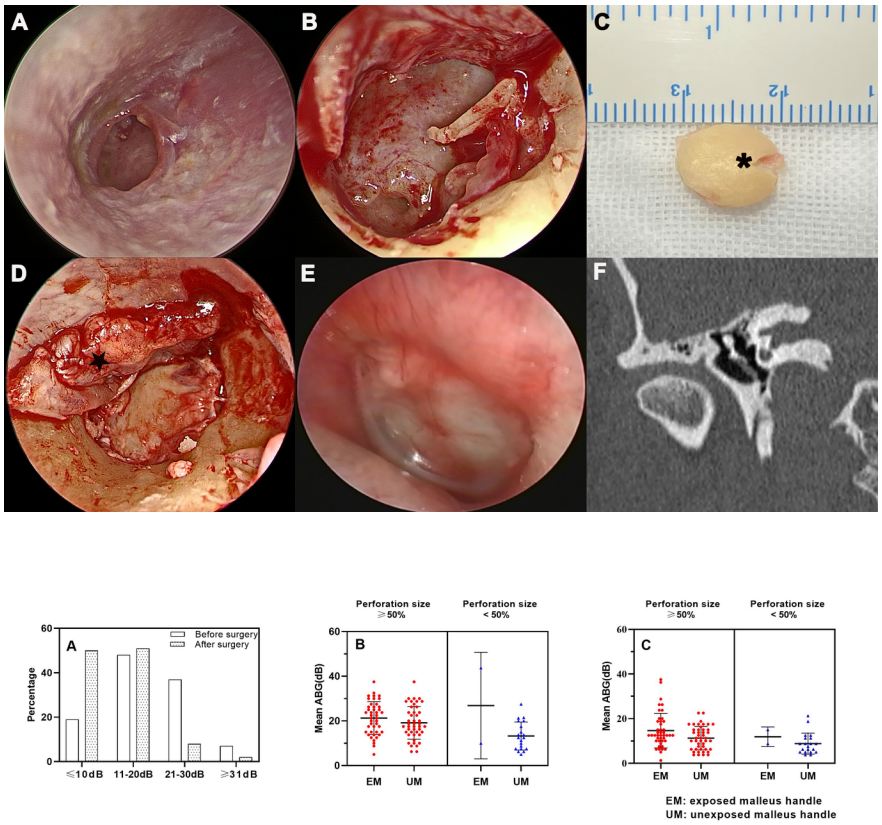
Figure Legends

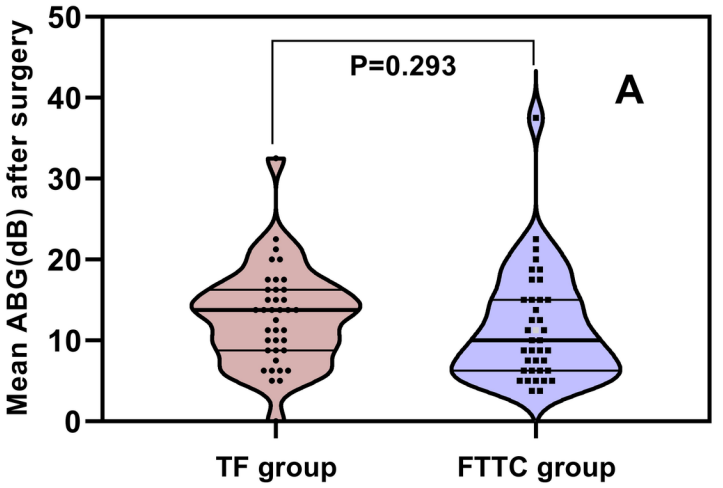
Figure 1A. Tympanum perforation before surgery. B. The malleus handle with removed epithelium. C. Full-thickness tragal cartilage with a "V" shape (*). D. the graft placed appropriately between the malleus handle

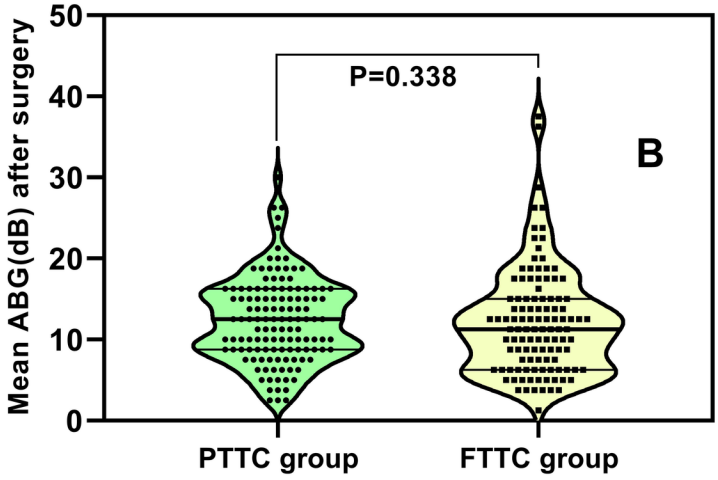
and the tympanomeatal flap (star). E. Postoperative tympanum 3-months after surgery. F. The relationship between the postoperative tympanum and the malleus handle on reconstructed computed tomography scan.

Figure 2. Mean air-bone gap (ABG) before and after myringoplasty with full-thick tragal cartilage graft. A. ABG distribution before and after surgery. B, C. The impact of tympanum perforation size and malleus handle exposure status on the mean ABG before and after surgery.

Figure 3. Comparison of the mean postoperative air-bone gap (ABG) A. Comparison of mean ABG between temporalis fascia and full-thickness tragal cartilage groups B. Comparison of mean ABG between partial-thickness tragal cartilage and full-thickness tragal cartilage groups.







TF: temporalis fascia
FTTC: full-thickness tragal cartilage
PTTC: partial-thickness tragal cartilage