ORIGINAL ARTICLE

Endoscopic atticotomy for attic cholesteatomas using piezosurgery

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Abstract

Background: Attic cholesteatomas can be exenterated by transcanal endoscopic ear surgery (TEES). In the limited operative field of exclusive transcanal endoscopic atticotomy, surgeons use either a piezosurgery scalpel or a drilling system to remove the posterior lateral bony wall of the epitympanum. We aimed to investigate the feasibility of using piezosurgery or microdrill for endoscopic atticotomy during exenteration of attic cholesteatomas.

Methods: This study is a retrospective chart review of patients diagnosed with attic cholesteatoma, who were treated by exclusive TEES. The superior and posterior external auditory canal bones were excised using a piezosurgery scalpel or microdrill. Preoperative and postoperative hearing thresholds were measured by pure-tone audiometry.

Results: The postoperative follow-up duration varied from 6 to 37 months. There were no significant differences in age, sex, laterality of the affected ear, and preoperative bone conduction thresholds between the piezosurgery scalpel and microdrill groups. The operative duration was longer in the piezosurgery group than in the microdrill group (135.6 ± 19.5 minutes vs 117.3 ± 29.1 minutes, $p = 0.042$). Seven of 30 (23.3%) patients in the microdrill group, but none in the piezosurgery group, had a friction injury from the drilling. Postoperative testing at higher frequencies of 2000, 3000, and 4000 Hz showed no deterioration in the bone conduction threshold in the piezosurgery group.

Conclusion: Endoscopic atticotomy performed using a piezosurgery scalpel is potentially safer but slower than using a microdrill for exenteration of attic cholesteatomas.

Keywords: Attic cholesteatoma; Atticotomy; Endoscopic ear surgery; Microdrill; Piezoelectric surgery; Piezosurgery

1. INTRODUCTION

Attic cholesteatoma is destructive to the epitympanum and is usually treated by microscopic ear surgery (MES) with microdrills, which may damage the surrounding soft tissues and nerves.[1,2] Compared with MES, transcanal endoscopic ear surgery (TEES) has some advantages, such as being more minimal invasiveness, better access to the middle ear, less pain, faster recovery, comparable postoperative outcomes, and better cosmetic results.[3,4] TEES has been gaining attention after exclusive management of attic cholesteatomas by Tarabichi.[5] A systematic review by Presutti et al[6] concluded that cholesteatomas treated by TEES was minimally invasive and its rates of recurrence and residual disease were similar to those achieved with traditional microscopic procedures.

Otologic piezosurgery is performed using a novel ultrasonic scalpel. The instrument creates microvibrations (between 60 and 210 μ) at a low ultrasonic frequency (24-29.5 kHz), which facilitates precise dissection. Piezosurgery can reduce injuries of surrounding soft tissue. Salami et al[7] reported their experience of successful piezosurgery for different types of ear surgeries, including atticoantrostomy, canal wall up mastoidectomy, and cochleostomy. However, most studies discuss piezosurgery performed with a two-handed technique under a microscope. Ear surgery using a one-handed technique with an endoscope and a piezoelectric scalpel is rare. There are no studies discussing inner ear function with both piezosurgery and microdrills in atticotomy.

In the limited operative field of exclusive transcanal endoscopic atticotomy, surgeons use either a bone curette or a drilling system[5,8] to remove the posterior lateral bony wall of the epitympanum. Care needs to be taken to avoid accidental damage to the surrounding soft tissues, such as the tympanomeatal flap, chorda tympani nerve, and facial nerve. Herein, we describe our experience of using piezosurgery and microdrills for TEES. We aimed to compare the outcomes of piezosurgery and microdrill for endoscopic atticotomy during exenteration of attic cholesteatomas.

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Conflicts of interest: The authors declare that they have no conflicts of interest related to the subject matter or materials discussed in this article.

Journal of Chinese Medical Association. (2024) 87: 236-241.

Received June 8, 2023; accepted October 8, 2023.

doi: 10.1097/JCMA.0000000000001045

2. METHODS

2.1. Patients

We performed a retrospective chart review of 46 patients diagnosed with attic cholesteatoma, who were surgically treated by exclusive TEES. This retrospective study was performed in accordance with the Declaration of Helsinki and was approved by the Medical Ethics Committee of Chang Gung Memorial Hospital (IRB: 202000200B0C501). All enrolled patients had attic cholesteatoma on computed tomography. Patients with class 1 extension, including classes 1a and 1b, eg, limited epitympanum involvement, according to the EAONO/JOS classification system[9] were included. The patients had not previously undergone a surgical procedure for cholesteatoma. Of these, 16 and 30 procedures used piezosurgery (Fig. 1A) and a microdrill, respectively.

Major presenting symptoms of the patients included otorrhea, aural fullness, hearing loss, and tinnitus on the affected side, and most patients experienced more than one symptom. All patients underwent otoscopy, pure-tone audiometry (PTA), tympanometry, and high-resolution computed tomography of the temporal bones preoperatively, and provided informed consent for the surgery.

2.2. Procedure

Patients were operated under general anesthesia. Rigid endoscopes (Karl Storz, Tuttlingen, Germany), with shafts 3 mm in diameter, 14 cm in length, and 0° and 30° lenses, were used with a high-definition monitor and 3-charge coupled device (3-CCD) camera head (Karl Storz, Tuttlingen, Germany). The piezosurgery device (Piezosurgery®; Mectron Medical Technology, Genoa, Italy) consisted of an insert (MP3-a3o) with a shank length of 35 mm, diameter of 2.4 mm, scalpel angle of 30°, and a standard handpiece (Fig. 1A). The power and frequency settings of the device were 25 W and 24 to 36 kHz, respectively.

After injecting 2% lidocaine with 1:20 000 epinephrine into the bony ear canal, the tympanomeatal flap was elevated and rolled anteriorly. The superior and posterior external auditory canal bones were exposed, and the outer attic wall, including part of the scutum, was excised using a piezosurgery scalpel and microdrill (2-mm diameter, Medtronic ENT round fine diamond bur) (Fig. 1B, C) in 16 and 30 patients, respectively, to expose the tegmen tympani, thus revealing the ossicles and cholesteatoma sac. The "underwater" technique with high-speed distilled saline irrigation was used during the surgeries to decrease airborne dust and facilitate visualization. Expanded bone removal during atticotomy was monitored meticulously to prevent injury to the surrounding vital structures. The cholesteatoma sac was identified, fully exposed, and extracted from the attic. The sinus tympani and anterior epitympanum were thoroughly examined using endoscopes (with 0°, 30°, and 45° lenses) to ensure there was no residual cholesteatoma.

Ossicular reconstruction was performed using a partial ossicular replacement prosthesis. The lateral attic wall and tympanic membrane were reconstructed using tragal cartilage and a perichondrial graft. The tympanomeatal flap was then repositioned and secured with ofloxacin-soaked gelfoam to prevent lateralization. All patients were followed up postoperatively at our outpatient department for at least 6 months.

2.3. Individual outcome measures

Intraoperative and postoperative complications (monitored during each postoperative follow-up visit), postoperative audiometry results at 6 months, and disease recurrence were recorded. The duration of surgery was calculated as the time between the beginning of local anesthesia injection and the end of external auditory canal packing. We did not intentionally break down the time required for each individual step in between. Considering all other steps are the same except for the instruments used, the difference in surgical duration between the two procedures can be attributed to the utilization of distinct instruments for bone cutting.

2.4. Sample size

G*power version 3.1 was used to determine the sample size.[10] Based on the preceding analysis with effect size, a sample size of n = 16 in each group was necessary for achieving a power of 0.8 at $\alpha = 0.05$.

2.5. Statistical analysis

Statistical analyses were conducted using SPSS (version 24.0; IBM SPSS, Chicago, IL). Continuous variables are expressed as mean and SD, while categorical variables are expressed as a percentage (%) of the total number of cases. Effect sizes with 95% CIs were calculated for all variables. Categorical variables were analyzed using the Pearson's χ^2 test. The Mann–Whitney *U* test was used to compare continuous variables that were not normally distributed. Statistical significance was set at $p < 0.05$.

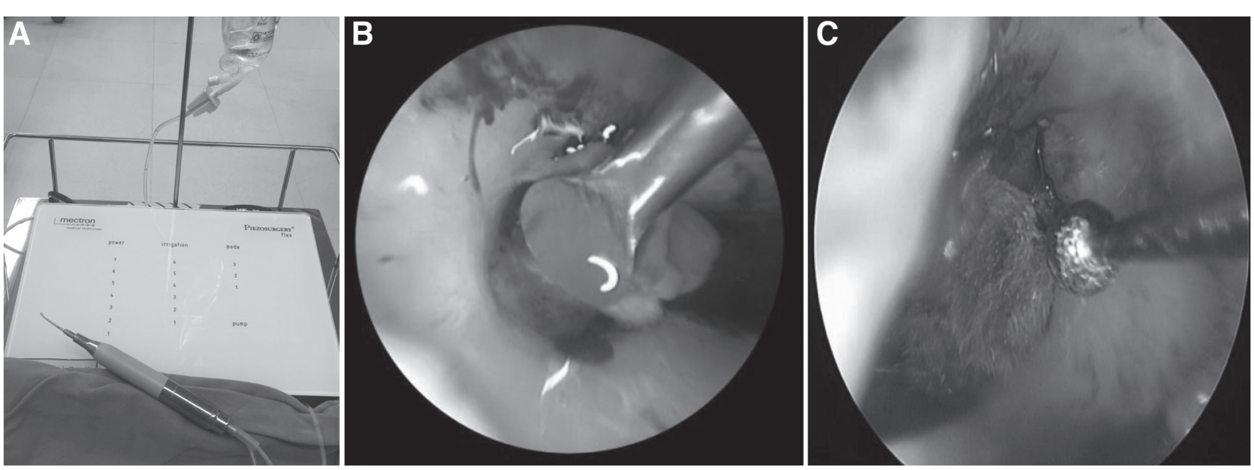

Fig. 1 Images of the piezosurgery device and a microdrill. A, Piezosurgery machine and handpiece. B, Piezosurgery. C, Microdrill.

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3. RESULTS

Baseline demographic characteristics of all the patients (N = 46) are summarized in Table 1. All patients underwent primary TEES (piezosurgery: N = 16, age = 47.5 ± 15.9 years; microdrill: N = 30, age = 48.1 ± 15.9 years; effect size, 0.04; 95% CI, –9.36 to 10.49; $p = 0.896$, Mann–Whitney *U* test) without subsequent revision procedures. There were no significant differences in age, sex, laterality of the affected ear, and preoperative bone conduction (BC) hearing thresholds between the two groups.

The postoperative follow-up interval was 6 to 37 months. No major operative complications, such as facial nerve injury, tegmen or dura injury, chorda tympani injury, or lateral semicircular canal injury, were observed in either group. Minor damage to the external auditory canal skin and tragus perichondrium was observed in 23.3% (7/30) and 13.3% (4/30) of patients in the microdrill group, respectively (Table 1). One patient in the piezosurgery group reported one episode of otorrhea during a follow-up visit, which resolved after treatment with antibiotic ear drops. No other adverse effects were reported or observed. While three patients in the microdrill group experienced recurrent cholesteatoma, all patients in the piezosurgery group showed complete remission with no recurrence during the study period. The operative time was longer in the piezosurgery group than in the microdrill group (135.6 ± 19.5 minutes vs 117.3 ± 29.1 minutes; effect size, –0.30; 95% CI, –34.61 to –1.85; $p = 0.042$, Mann–Whitney *U* test) (Fig. 2).

Postoperative testing at frequencies of 2000, 3000, and 4000 Hz showed no deterioration in the BC threshold in the piezosurgery group (Table 2, Fig. 3A); however, in the microdrill group, one (3%), two (7%), and three (13%) patients had a 10-dB drop in the BC threshold at 2000, 3000, and 4000 Hz, respectively (Fig. 3B).

4. DISCUSSION

The present study findings demonstrate the effectiveness of piezosurgery and microdrill in TEES for attic cholesteatoma exenteration. Our results reveal that piezosurgery is slower than a microdrill but a potentially safe alternative with a lower risk of damaging the skin of the external auditory canal, tympanomeatal flap, tragal perichondrium and cartilage, chorda tympani, or inner ear function in exclusive trascanal**** endoscopic atticotomy.

There is no consensus on the optimal technique for exenteration of cholesteatomas limited to the attic. The choice of surgical technique usually depends on factors including the extent of disease, operating surgeon's preference or experience, and institution's resources. TEES has evolved from being a simple adjunct to microscopic operations, to an exclusive procedure of the middle ear in the past decade.[6,11–13] It has the advantage of being minimally invasive and is associated with rates of recurrence and residual disease comparable to those achieved with conventional microscopic operative techniques.[14,15] In 2020, a randomized controlled trial conducted by Das et al[16] revealed that an endoscopic approach was better than conventional microscopic surgery for the management of limited attic cholesteatomas.

Conversely, drawbacks of TEES include the necessity of a one-handed operating technique, lack of true depth perception due to the two-dimensional view offered by the endoscope, and limited operative field. In clinical practice, the first two disadvantages can be overcome following the completion of a learning curve. However, a limited surgical field can render an endoscopic atticotomy procedure difficult and risky, and this is where piezosurgery could play an important role. Conventionally, surgeons use a bone curette or microdrill to extract the scutum from within the narrow working space available during an endoscopic procedure. These instruments can inadvertently injure the surrounding soft tissues, such as the skin of the external auditory canal, tragal perichondrium, tympanic membrane, facial nerve, and chorda tympani nerve.[12,17–19] Moreover, a curette is cheaper, but harder to use for one-handed bony work in the lateral wall of the scutum than a microdrill or piezosurgery. However, precise dissection

Table 1

Demographics of the microdrill and piezosurgery groups

Variable	Microdrill (n = 30 ears)	Piezosurgery (n = 16 ears)	Effect size/OR (95% CI)[a]	*p*
Age, mean (SD), y	48.1 (15.9)	47.5 (15.9)	0.04 (–9.36 to 10.49)	0.896
Sex, n (%)				1.000
Male	12 (40.0)	6 (37.5)	1.07 (0.49-2.30)	
Female	18 (60.0)	10 (62.5)	0.96 (0.60-1.55)	
Diseased side, n (%)				0.217
Left	12 (40.0)	10 (62.5)	0.64 (0.36-1.14)	
Right	18 (60.0)	6 (37.5)	1.60 (0.80-3.21)	
BC thresholds, mean (SD), dB				
500	18.3 (16.2)	18.1 (12.2)	0.01 (–9.11 to 9.52)	0.913
1000	17.2 (13.1)	18.4 (12.5)	0.09 (–9.32 to 6.78)	0.691
2000	23.7 (16.8)	29.1 (12.9)	0.36 (–15.11 to 4.31)	0.261
3000	24.0 (17.3)	30.9 (11.9)	0.46 (–16.73 to 2.85)	0.106
4000	22.7 (19.4)	29.1 (12.4)	0.39 (–17.22 to 4.43)	0.092
Complications				
Injury to CTN	0 (0)	0 (0)	-	1.000
Damage to EAC skin	7 (23.3)	0 (0)	-	0.078
Trauma to tragal perichondrium	4 (13.3)	0 (0)	-	0.282
Damage to inner ear structure	0 (0)	0 (0)	-	1.000
Recurrence, n (%)	3 (10.0)	0 (0)	-	0.304
Follow-up, mean (SD), months	15.5 (10.2)	14.8 (10.0)	0.07 (–5.55 to 7.05)	0.914

BC = bone conduction; CTN = chorda tympani nerve; OR = odds ratio.

[a]For continuous variables, the effect size was estimated by the difference in medians between the groups, and the 95% CI around that difference was calculated using Cohen's d method for the Mann–Whitney *U* test. For categorical variables, effect size was estimated by the difference in proportions between the groups, with the relative 95% CI calculated around that difference.

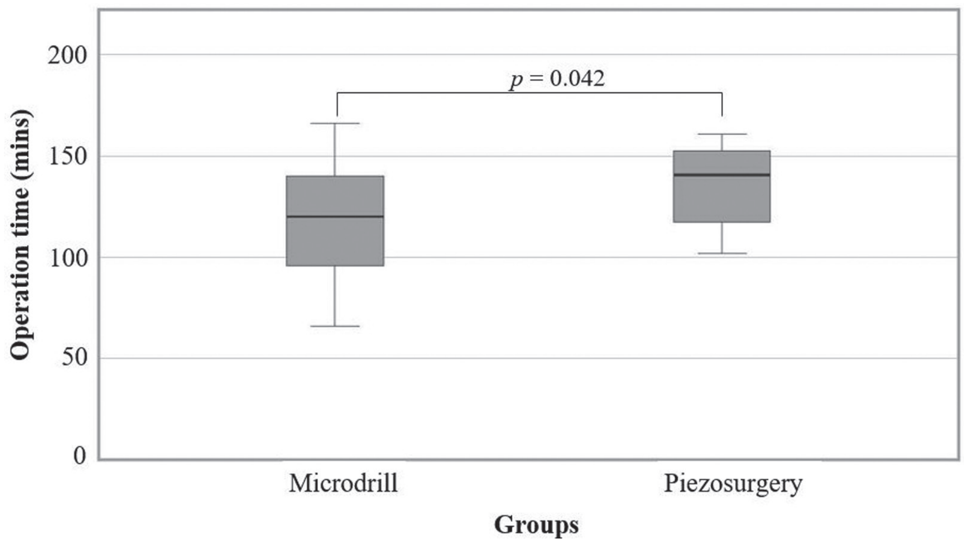

Fig. 2 Comparison of operative durations between the two patient groups.

Table 2

Change of bone conduction thresholds in the microdrill and piezosurgery groups

Variable	Microdrill (n = 30 ears)	Piezosurgery (n = 16 ears)	Effect size/OR (95% CI)[a]	p
500	1.3 (7.4)	−1.6 (5.1)	0.46 (−0.85 to 6.64)	0.132
1000	2.0 (5.7)	0.6 (5.4)	0.25 (−2.11 to 4.86)	0.366
2000	3.7 (4.9)	4.1 (4.6)	0.08 (−3.38 to 2.59)	0.918
3000	1.8 (5.3)	3.8 (3.9)	0.43 (−4.96 to 1.13)	0.297
4000	0.7 (6.1)	2.2 (4.8)	0.27 (−5.08 to 2.04)	0.424

OR = odds ratio.

[a]For continuous variables, the effect size was estimated by the difference in medians between the groups, and the 95% CI around that difference was calculated using Cohen's d method for the Mann–Whitney *U* test. For categorical variables, effect size was estimated by the difference in proportions between the groups, with the relative 95% CI calculated around that difference.

of the scutum using piezosurgery may compensate for this shortcoming. Variable frequency modulation makes the insert vibrate at a specific frequency, which keeps the cutting tip clear of bone splinters and increases the efficacy of dissection. The bony tissue is incised within a shorter time, without inducing an excessive increase in tissue temperature, thus decreasing the possibility of thermal injury as compared to that observed with a microdrill. Furthermore, interoperative irrigation also cools the bone and removes blood from the operative field, offering better visibility.[20,21] We recommend the use of continuous high-speed saline irrigation and the "underwater" technique to remove the bony dust during atticotomy. We used an insert (MP3-a3o) with a cutting tip of 2.4 mm diameter and scalpel angle of 30°, allowing it to fit within the narrow endoscopic surgical field. Its microvibrations enabled clean, precise, and efficient cutting, and allowed easy excision of the lateral attic and posterosuperior bony ear canal wall during the atticotomy. It is important to address the potential issue of skin damage when using the ultrasonic osteotome, particularly in relation to the external auditory canal. Given that the external auditory canal is a narrow and elongated passage, there is a possibility that the ultrasonic bone knife might come into contact with the skin of the canal. To mitigate this risk, we used endoscopic guides to ensure proper positioning of the ultrasonic osteotome to minimize the chances of skin contact. There was no accidental event of skin trauma from ultrasonic osteotome.

Kim et al[22] reported improvement in postoperative hearing after an atticoantrostomy with attic reconstruction in patients with attic cholesteatoma. Recent studies have shown comparable outcomes with respect to the recovery of hearing loss for TEES and conventional microscopic surgery.[16,17,23] However, the possibility of postoperative sensorineural hearing loss (SNHL), which may be associated with several factors—including incidental ossicular chain injury, cochlear damage, acoustic trauma caused by drilling, and prolonged exposure to the drilling noise in middle ear procedures[24,25]—must be considered. With TEES, drilling for atticotomy can be performed without mastoidectomy, which renders the procedure less time-consuming and enables a more meticulous endoscopic approach. It prevents inadvertent intraoperative injury to the middle and inner ear structures. Glikson et al[17] reported the occurrence of 5% SNHL after TEES, which they concluded was due to extensive disease involving the oval/round window and postoperative labyrinthitis. In our study, a 10-dB drop in BC threshold was observed in the microdrill group during postoperative testing at higher frequencies.

In contrast, a previous study reported the safety of piezosurgery for cochlear outer hair cells and other anatomical structures of the middle and inner ear, thus conserving auditory function.[26] The piezoelectric scalpel could incise bony structures without causing necrosis or damage to the surrounding non-mineralized tissues (nerves, vessels, dura mater, etc) that incidentally came into contact with the cutting tip. Piezosurgery causes lesser postoperative pain than that experienced with microdrills.[27] In our piezosurgery group, postoperative evaluations at 2000, 3000, and 4000 Hz, which are related to noise, showed no deterioration in the BC threshold. The longer operative duration in the

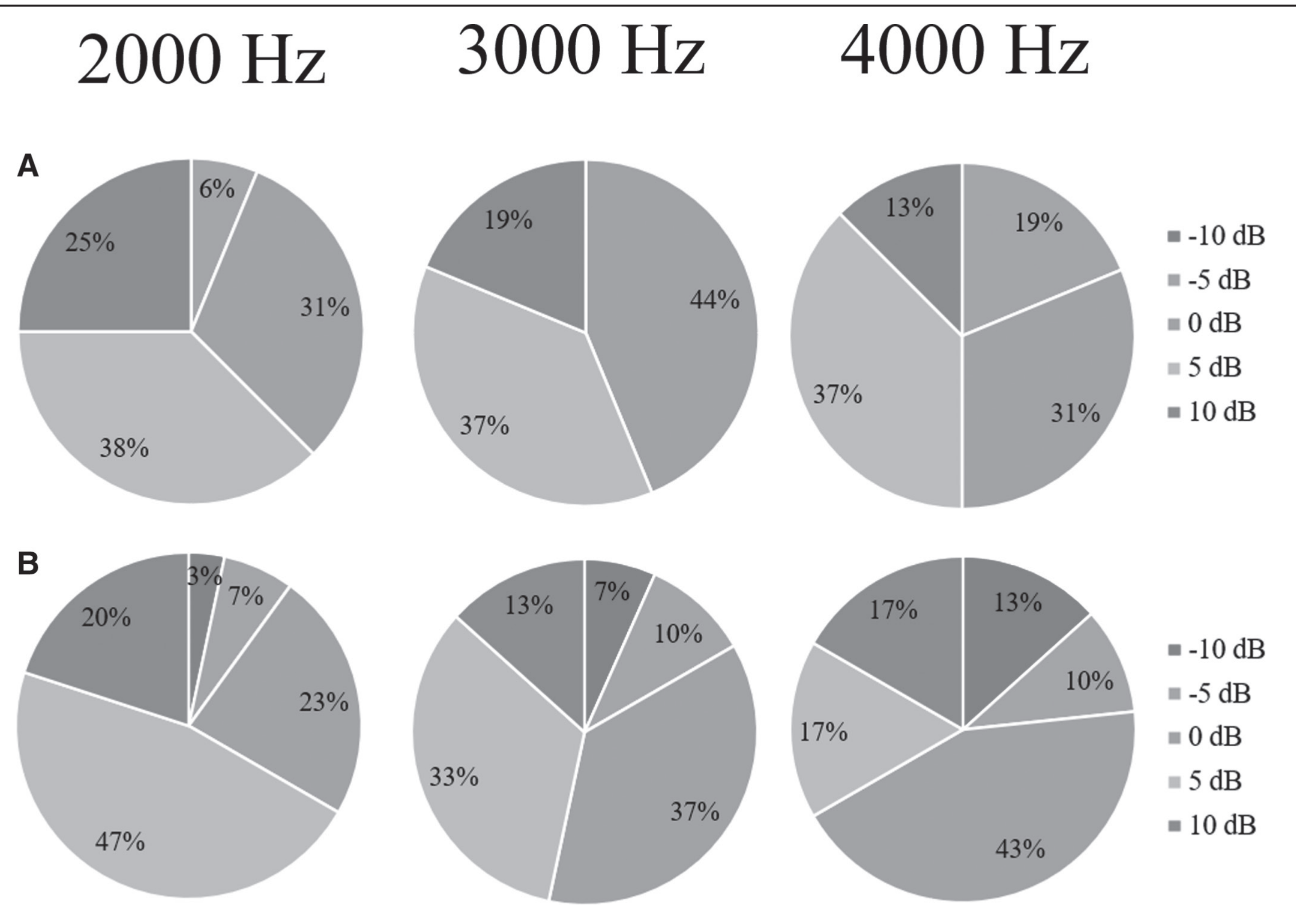

Fig. 3 Percentage of the bone threshold drop between the two patient groups. A, Piezosurgery group. B, Microdrill group.

piezosurgery group than in the microdrill group did not lead to hearing damage. These results indicate that endoscopic atticotomy performed using piezosurgery for exenteration of attic cholesteatomas may not lead to postoperative SNHL.

This study had several limitations. First, we only included patients with well-encapsulated cholesteatomas based on computed tomography findings. Patients with more extensive or infiltrative disease were excluded, which may have introduced a degree of selection bias. Second, one may use a Visao curved round fine diamond bur instead of traditional microdrills to reduce injury to the tragal cartilage, tragal perichondrium, and tympanomeatal flap. Thus, the access of a Visao bur may shorten the operative time than a piezosurgery scalpel in endoscopic atticotomy. Third, TEES is usually conducted through one-handed technique, and the ultimate surgical outcome can be influenced by surgeon's expertise and technical proficiency.

In conclusion, exenteration of limited attic cholesteatomas by transcanal endoscopic atticotomy using a piezosurgery device facilitates removal of the diseased tissue while preventing inadvertent injury to the surrounding vital structures. TEES with a piezosurgery scalpel shows potential to be a safer alternative but slower than a microdrill for the operative management of affected patients.

ACKNOWLEDGMENTS

This study was supported by the Chang Gung Memorial Hospital (Linkou, Taiwan) under the Grant Number CMRPG3K2001.

The authors would like to thank Ms. Ling-Hsuan Chuang for assistance in data collection and statistical analyses.

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