



Clinical and audiometric outcomes of palisade cartilage myringoplasty under local anesthetic in an office setting[☆]

Nael M. Shoman*

Dalhousie University, Canada

ARTICLE INFO

Keywords:

Myringoplasty
Tympanoplasty
Local anesthesia
Cartilage

ABSTRACT

Objective: Assess clinical and functional outcomes of a modified palisade cartilage-perichondrium graft myringoplasty under local in an office setting.

Study design: Retrospective case series.

Setting: Tertiary care facility.

Patients: Patients with a tympanic membrane perforation presenting between March 2013 and October 2017. Inclusion criteria included age ≥ 7 years, entire perforation margin visualized through a transcanal view, and the ability to lie supine for up to 45 min. Exclusion criteria included a conductive hearing loss larger than expected, and presence of active infection.

Intervention: In-office modified myringoplasty technique under local anesthesia without sedation.

Main outcome measures: Complete perforation closure rate and audiometric outcomes.

Results: 250 patients underwent the procedure, of whom 13 had bilateral sequential procedures (total 263 ears). Of those, 197 were primary and 66 revision. Average age was 46.3 years. Perforation sizes were categorized as small (32), moderate (109), large (78), and subtotal (44). Complete perforation closure was evident in 219 of the 250 cases (88%). Preoperative mean air pure tone average (PTA) was 56.7 dB and mean bone PTA was 27.5 dB (pre-operative ABG 29.2 dB). AC-PTA significantly improved to 35.0 dB ($p < 0.0001$), and ABG to 9.6 dB ($p < 0.0001$). Only subtotal perforations showed a statistically significant negative relationship with outcome ($p = 0.04$).

Conclusion: The modified palisade cartilage-perichondrium graft myringoplasty under local anesthetic is a highly successful procedure well tolerated by adult and pediatric patients with variable perforation sizes. This may have significant potential patient benefits, as well as cost savings to the health care system.

1. Introduction

Since tympanoplasty was described in 1952 [1,2], it has become a common procedure in otolaryngology practice. Over the years, various modifications have been introduced, with the use of different materials including fascia, perichondrium, adipose tissue, synthetic materials, and cartilage [3]. While overall success rates are high for these various materials in normal circumstances, the prognosis is worse in cases of underlying Eustachian tube dysfunction, middle ear mucosal disease, active middle ear infection, tympanic fibrosis and large and subtotal tympanic membrane perforations [4–6]. In these high risk ears, some authors have reported better results for cartilage tympanoplasty techniques compared to fat or fascia [7–10].

Advances have also been made in an effort to simplify the

procedure, with techniques described to avoid an ear canal incision or the need for packing, shorten surgical time, and avoid general anesthetic [11–13]. In 1998, Eavey described the cartilage “butterfly” inlay technique in pediatric patients as a simpler approach done with mask inhalation, with no canal incisions, and a split thickness skin graft [14]. Then, in 2000, Lubianca-Neto modified this technique to be used in adults under local anesthetic without the use of skin grafts, and subsequent studies have shown success rates ranging from 71% to 96% [15,16]. Saliba et al. described hyaluronic acid fat graft myringoplasty (HAFGM) as a simple technique to close tympanic membrane perforations of variables sizes in pediatric and adult patients under local anesthetic [12,17].

Since the first description of cartilage by Jansen [18] and Salen [19], its use has been further modified over the years including the

[☆] The author acknowledges that there are no conflicts of interest to declare.

* QEII Health Sciences Centre, 3184 Dickson Building, 5820 University Avenue, Halifax, NS B3H 2Y9, Canada.

E-mail address: shoman@dal.ca.

palisade and the shield techniques. At our institution, we have adopted some of the principles of the underlay palisade cartilage technique, and modified that so as to be undertaken in an office setting, under local anesthetic, and without canal cuts. The current study describes the procedure, and assesses clinical as well as audiologic outcomes.

2. Methods

This was a retrospective study assessing the anatomic and functional results of office based cartilage myringoplasty under local anesthetic. Between March 2013 and October 2017, a list of all patients who presented with a tympanic membrane perforation and underwent myringoplasty under local anesthetic in an office setting was retrieved. Thereafter, these patients had their charts reviewed. Patients with a tympanic membrane perforation of any size that met study criteria were offered either surgical closure under general anesthetic using a formal tympanoplasty procedure, or closure under local anesthetic using a composite cartilage-perichondrium graft. Inclusion criteria for the latter included age ≥ 7 years, any perforation size as long as the entire perforation margin is visualized through a transcanal view, and the ability to lie supine for up to 45 min. Exclusion criteria included a conductive hearing loss larger than can be accounted for by the perforation size, presence of middle ear or mastoid cholesteatoma, and active middle ear infection.

Ethics approval for the study was obtained from our institution.

2.1. Description of procedure

The procedure was done in an otology examination room set up with an otologic microscope but otherwise no monitoring equipment. In the supine position with the head turned to the contralateral side, the surgical ear is prepped with betadine and then draped in a sterile fashion. The ear canal is then flushed with saline. Lidocaine with epinephrine is used to infiltrate the posterior canal wall in a slow and deliberate manner using a single injection in the lateral mid posterior aspect. Lidocaine with epinephrine is then used to infiltrate the posterior aspect of the tragus. The perforation is visualized and any thick sclerotic plaques are removed using a short right angle pick. Thereafter, the short right angle pick is used to freshen the perforation margin as well as the immediate undersurface extending 2 mm past the margin on the medial aspect. If the perforation extends to the anterior sulcus, then the medial ear canal skin anteriorly is elevated 2 mm off the bone. Likewise, if the perforation extends to the posterior bony margin, then the medial ear canal skin posteriorly is elevated 2 mm off the bone. If the perforation involves the malleus, then epithelium is denuded off the distal malleus handle.

Cartilage is then harvested from the tragus in a standard fashion, in such a way that perichondrium is still intact on one side. The graft size is dependent on the perforation size. The cartilage is thinned, with perichondrium maintained on one side. Then, this composite graft is cut into smaller pieces, the number of pieces depended on perforation size and shape. Each piece is fashioned as a “cartilage island” with perichondrial tails extending 2 mm circumferentially around the cartilage.

The middle ear is then gently packed with Gelfoam with steroid solution. Tympanic membrane perforation repair is done in a palisade fashion. Each composite graft is placed so as to have perichondrium facing laterally, and the perichondrial tails extending medial to the perforation margin and extending 2 mm past this margin. Grafts are similarly positioned “interlocking” the adjacent cartilage graft with the tail of one piece passing medial and the tail of the other piece extending lateral to the adjacent cartilage edge. When the malleus is involved, the perichondrial tail wraps around the handle, medial to it distally and then passing lateral to it proximally. For a perforation that extended to the anterior sulcus, the cartilage is extended just to the bony annulus, the perichondrium passed onto the medial bony canal under the elevated skin (2 mm), and then skin is repositioned over the

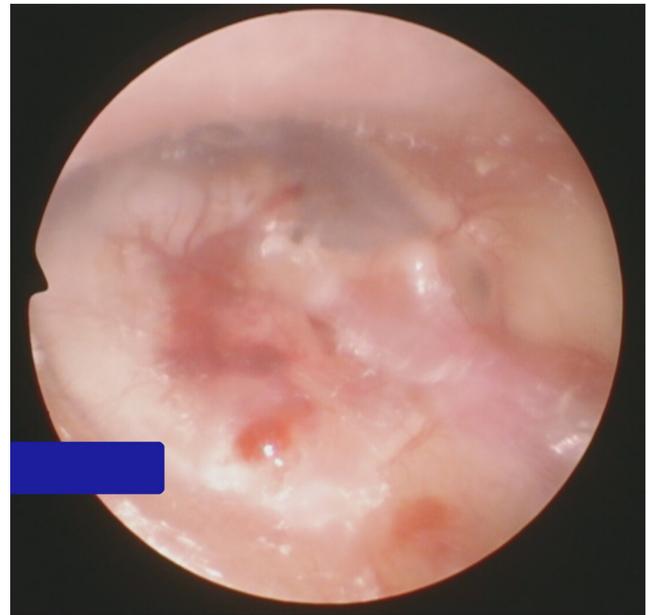


Fig. 1. Endoscopic view left tympanic membrane at three weeks following palisade cartilage myringoplasty for a large central perforation.

perichondrium. Once the perforation is closed in this systematic fashion, the medial ear canal is gently packed with Gelfoam impregnated with topical antibiotic solution.

Timing for procedure length was measured by documenting time of initial local injection of lidocaine, to time of removal of drapes at the end.

2.2. Outcome measures

A baseline preoperative hearing assessment was obtained in all cases. Patient demographics were recorded as well as intraoperative details and any perioperative complications. Patients were then seen three weeks following the procedure and the Gelfoam packing removed from the ear canal to assess the status of the graft. Fig. 1 demonstrates an endoscopic view of a left tympanic membrane at three weeks that underwent the procedure for a large central perforation. Fig. 2 demonstrates an endoscopic view of a right tympanic membrane three months postoperatively from repair of a subtotal perforation using the palisade technique. Subsequently, patients were seen in another month and a hearing test was done at that time. Patients were subsequently assessed in about 6 weeks after and a hearing test repeated again at that appointment, and then again at one year.

The main outcome measures used were graft success rate and hearing improvement level. Graft success was defined as complete healing of the tympanic membrane without perforation or lateralisation for at least 6 months post-operatively. The guidelines of the American Academy of Otolaryngology—Head and Neck Surgery Committee on Hearing and Equilibrium were used to determine functional outcomes.

Hearing outcomes were calculated from the latest audiogram available and comparing the pre- and post-operative air conduction (AC) and bone conduction (BC) pure tone averages (PTAs) at 0.5, 1, 2 and 3 kHz. The air bone gap (ABG) was calculated from this information. Hearing gain was defined as the difference between the pre- and post-operative ABG.

2.3. Statistical analysis

Data were analyzed using SPSS 24 (IBM Chicago, Illinois, USA). Statistical comparisons were made using one-way analysis of variance, the chi-square test, and the *t*-test for independent samples. The results

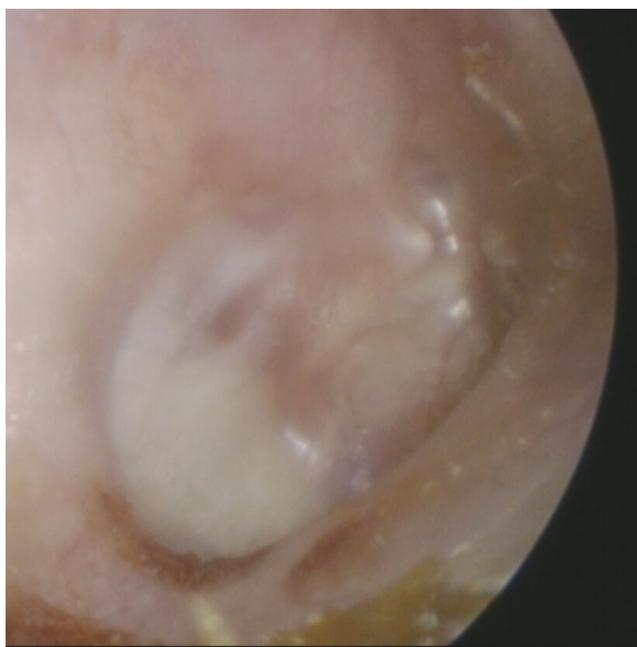


Fig. 2. Endoscopic view right tympanic membrane at three months following palisade cartilage myringoplasty for a subtotal perforation.

were assessed within a 95% reliance, and at a significance level of $p < 0.05$.

3. Results

A total of 250 patients underwent the procedure under local anesthetic during the study period. Of those, 13 patients had bilateral sequential procedures for a total of 263 ears. The average age was 46.3 years (SD 20.0, median = 45.0, range 7–92 years). Twenty three patients were 18 years old or younger (two under the age of 13, one being 7 and the second 12 years old). There were 154 females (62%). Of 263 ears, 142 were left sided (54%).

Of 263 operative ears, 197 were primary procedures and 66 (25%) were revision from prior failed tympanoplasty under general anesthetic. The range of perforation sizes as well as location is summarized in Table 1. Perforations were defined as small if the size was < 30% of the pars tensa, moderate if the size 30–50%, large if the size 50–90%, and subtotal if > 90%.

Average operative time was 32 min (range 14–57 min). Two patients (0.8%) had temporary facial paralysis from local anesthetic infiltration that completely resolved within a few hours. The most common complication was immediate post operative vertigo and nausea. This occurred in 28 procedures with an overall incidence of 11%, and it was noted shortly after the patient attempted to get up from the supine position at the end of the procedure.

Assessment of surgical success was statistically analyzed for the 250 patients, as opposed to the independent analysis of sequential ears done in the same patient. Successful surgery, defined as graft take with complete perforation closure, was evident in 219 cases (88%). Of those,

Table 1
Cohort evaluation based on perforation size and associated success rate.

Perforation size	N (%)	Success (%)
Small	32 (12%)	30 (94%)
Moderate	109 (41%)	97 (89%)
Large	78 (30%)	71 (91%)
Subtotal	44 (17%)	34 (77%)
Total	263 (100)	232 (88%)

Table 2
Cohort evaluation based on perforation location and associated success rate.

Perforation location	N (%)	Success (%)
Anterior	104 (40%)	93 (89%)
Central	49 (19%)	43 (88%)
Posterior	56 (21%)	52 (93%)
Inferior	8 (3%)	8 (100%)
Pars flaccida	2 (1%)	2 (100%)
Subtotal	44 (17%)	34 (77%)
Total	263 (100%)	232 (88%)

4 cases initially had a pinhole perforation seen on the first post operative visit (three weeks) which then spontaneously closed on the subsequent follow up visit at six weeks postoperatively. Tympanic membrane perforation closure outcomes based on size and location is summarized in Tables 1 and 2. There were no significant differences in surgical outcome and age, gender, and perforation location. Likewise, there was no significant difference in outcome between primary and revision cases. When analysing perforation size, only subtotal perforations showed a statistically significant relationship with unsuccessful outcome ($p = 0.04$).

Of the 31 cases that failed, 6 ears had a persistent pinhole perforation in between the palisade grafts. Of those, one elected to have it revised under a brief local anesthetic, while the remaining 5 opted to conservatively manage it as it did not bother them. Furthermore, 18 were revised under local anesthetic using a similar composite cartilage-perichondrium graft, and of those 16 were successful, and the remaining two were scheduled for a revision procedure under general anesthetic. Of the remaining 7 cases, 3 elected to have it revised but under general anesthetic, and 4 opted to defer any further surgical treatment. This data is summarized in Fig. 3.

Audiologic outcomes are summarized in Table 3. Mean air PTA at time of surgery was 56.7 dB and mean bone PTA was 27.5 dB, a pre-operative ABG of 29.2 dB. AC-PTA significantly improved from 56.7 to 35.0 dB ($p < 0.0001$). There were no differences between the pre- and post-operative values of BC-PTA ($p > 0.05$). ABG showed significant improvement from 29.2 to 9.6 dB ($p < 0.0001$).

There were no significant differences in the results of post-operative ABG, ABG gain and percentage ABG gain in male and female patients. Moreover, we found that age showed no disparity regarding ABG, ABG gain, percentage ABG gain, and BC-PTA gain ($p > 0.05$).

4. Discussion

The potential advantages to a modified surgical technique for tympanic membrane perforation closure that can be done under local anesthetic include avoiding general anesthetic and potential associated risks, avoiding canal cuts which could improve post operative patient comfort, faster recovery in the absence of systemic medications, and shorter surgical wait times. Furthermore, there are substantial cost savings to the care health system from avoiding operative room time.

The original introduction of the butterfly technique became popular amongst many authors as it minimized operative time and post operative healing yet it did have limitations including a limit on perforation size, the use of skin grafts, and general anesthetic. Its modification by Lubianca-Neto further promoted the technique, adding to its utility by showing its usefulness in adult patients, under local anesthetic, and without the need for skin grafts. The evolution in myringoplasty techniques under local anesthetic continued, and in 2008 Saliba et al. described HAFGM technique using neck fat. This has demonstrated high closure rates, yet did require a neck incision for fat harvesting, and required filling the middle ear with fat.

The principles in the current modified technique are based on a few concepts. Cartilage is considered a robust material with several advantages over temporalis fascia, and a recent meta-analysis

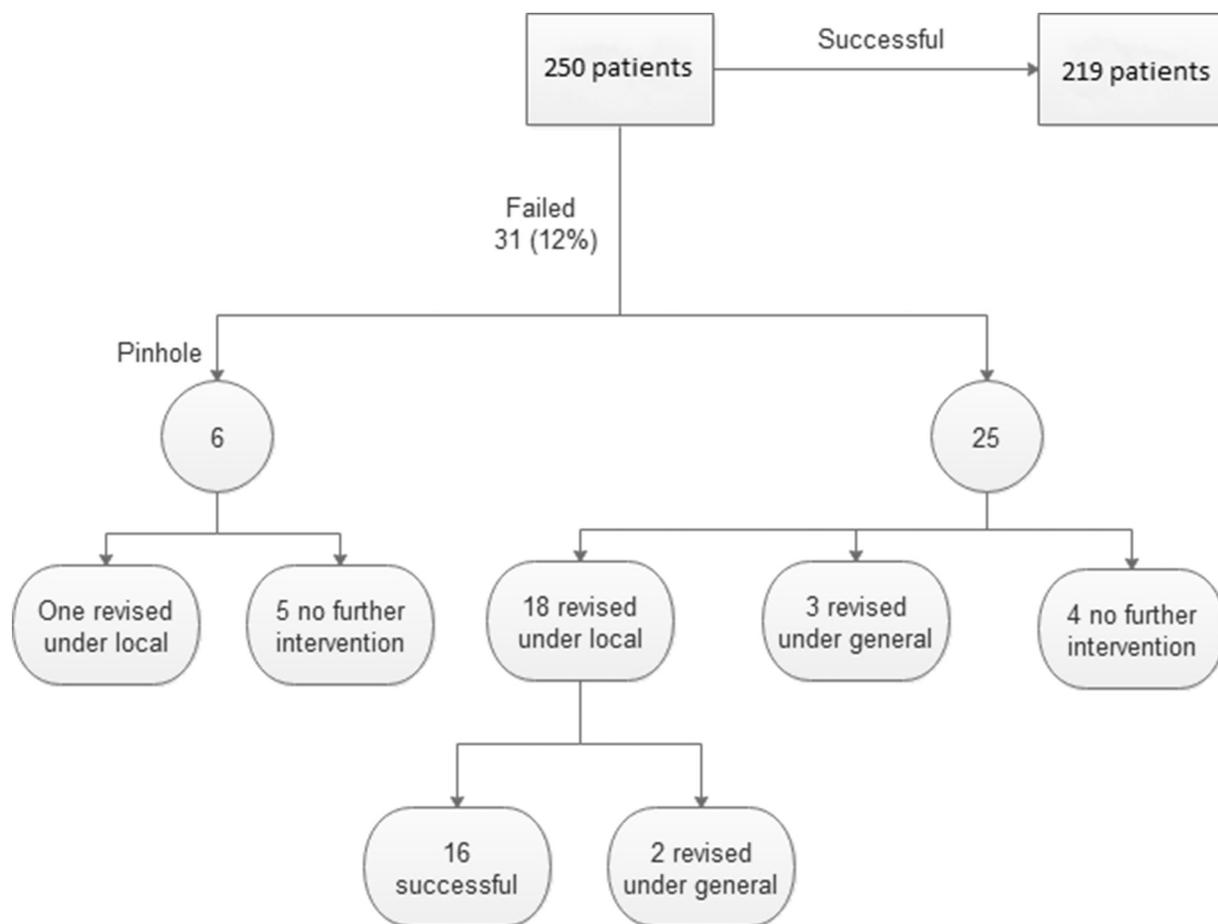


Fig. 3. Summary of clinical outcomes pertaining to post operative tympanic membrane closure.

Table 3
Pre and post operative audiological outcomes.

Parameter	Preop mean	Postop mean	Absolute difference
Discrimination (%)	96.4	98.2	1.8
Air PTA (dB)	56.7	35.0	21.7
Bone PTA (dB)	27.5	25.4	2.1
ABG (dB)	29.2	9.6	19.6

demonstrated that overall graft integration rates of tympanoplasty with cartilage graft and temporalis fascia graft are 92% and 82%, respectively [20]. Mohamad et al. [21] published a review of publications about tympanoplasty with or without mastoidectomy, and they found that tympanoplasty using cartilage with or without perichondrium had better morphological outcomes than tympanoplasty using temporalis fascia. In a recent study comparing the inlay butterfly transcanal cartilage tympanoplasty with the conventional underlay temporalis fascia tympanoplasty, both techniques had similar take rates and audiological results [16]. Laser Doppler vibrometric studies have shown that fascia has a much lower elastic modulus compared to the native tympanic membrane, making it more susceptible to retraction from negative middle ear pressure [22]. Favourable outcomes with cartilage as such become more evident in higher risk ears. For example, bilateral ear disease has been associated with higher failure rates [23–25], and a study comparing tympanoplasty outcomes with fascia and cartilage in patients with bilateral chronic otitis media found final tympanic closure rates 65.9% in the fascia group and 92.3% in the cartilage group [6].

Cartilage has a higher elastic modulus, proportionate to the thickness used, and it resists negative middle ear pressures to a much higher degree than fascia, and can be used in different thicknesses after

appropriate slicing [22,26,27]. The hearing outcomes with cartilage have previously been shown to be good despite concerns of its stiffness [28]. Studies have also shown that the size of perforation and the amount of cartilage used to close the perforation did not significantly change the postoperative hearing results [29,30]. In general, there are two distinct techniques commonly used for cartilage tympanoplasty, namely the perichondrium/cartilage island flap, and the palisade technique. The procedure described in the current study combines these two techniques to achieve tympanic membrane reconstruction of larger perforations without raising a tympanomeatal flap.

The palisade technique was first described by Heermann in 1962. While initially not very popular, its benefits have later been well demonstrated and it has emerged as a reliable technique especially in high risk tympanoplasty procedures. Kazikdas et al. found a 95.7% graft success rate for palisade cartilage grafts, compared with 75% for temporalis fascia grafts [4]. Vashisith et al. recently compared outcomes in fascia and palisade cartilage tympanoplasty and found that the cartilage palisade graft take-up rate was comparable to fascia but was significantly better in high-risk cases in the cartilage group, and that the hearing outcomes were significantly better in the cartilage palisade group after 1 year of follow-up [22]. A recent systematic literature review comparing graft take rates and hearing outcomes with cartilage and fascia found better hearing outcomes and closure rates in favour of cartilage (grade C strength of recommendation), and the rate of re-perforation also significantly lower with cartilage [31].

Tragal cartilage is slightly < 1 mm in thickness, and although it can be used as a full thickness graft with good audiometric outcomes [32], studies have suggested a slight acoustic benefit by thinning the graft to 0.5 mm [33]. One of the concerns often raised with thinning of the cartilage graft is curling. In the current technique, the cartilage graft

was thinned and the risk of curling minimized by, firstly, maintain perichondrium to create a composite graft, and secondly, palisading smaller grafts for moderate to larger perforations. Using smaller composite grafts that are palisaded not only afforded more control over the reconstruction, but was also found to minimize the risk of curling of each individual graft.

In the current study, there was significant improvement comparing pre and post operative ABG. The findings are similar to those found by Vashishth et al. [22], who found the mean ABG pre- and post-operatively in a cohort of patients that underwent palisade cartilage tympanoplasty was 29 ± 6.21 dB and 7.33 ± 3.88 dB, respectively. It is likely that various factors contributed to overall favourable outcomes in the current study, including a selection bias for favourable ears that can be done under local anesthetic, no elevation of a tympanomeatal flap, avoiding overlapping palisades, incorporation of the malleus handle, and anterior palisade placement medial to the bony annulus.

With proper patient selection, the described technique is effective in closing tympanic membrane perforations of any size under local anesthetic, as long as the entire perforation margin is visualized through a transcanal access. The high success rate is attributable to a number of factors. Firstly, while the initial description of the palisade technique involves only cartilage grafts, preservation of perichondrium intact on the cartilage and having “perichondrial tails” extending a couple of millimeters past the cartilage island adds flexibility as it allows for contouring medial to the perforation margin, and overlap between adjacent grafts. Perichondrium also helps with cartilage nourishment via diffusion, potentially improving survival in high risk fields, and is also vital for long-term graft survival [34]. Because the tympanic membrane assumes a concave configuration, the palisade technique affords needed flexibility to the reconstruction, particularly since no meatal flaps are elevated. Overlapping the perichondrial tails in juxtaposing cartilage grafts secures the grafts, and provides union between adjacent perichondrium via tissue fluid [22]. Finally, maintaining perichondrium only on the lateral aspect of the graft helps minimize the risk of adhesions in the middle ear.

The most common complication noted was post operative nausea and vomiting. Lidocaine has been shown as a cause of positional vertigo when applied to the middle ear [35]. To minimize this as a potential complication, slow infiltration of the posterior canal wall is important, in an effort to minimize lidocaine infiltrating the middle ear. This slow infiltration can also minimize the potential risk of temporary facial nerve weakness, which was noted in two patients in this study. The most common complaint from patients was the distress of hearing loud noises during the procedure. Adequate counselling before the procedure, use of smaller gauge suction tubes, and distraction during the procedure, have all been found to help with patient discomfort with the noise. Distraction measures included having a family member with the patient during the procedure, the use of smart phones or tablets to watch videos, and incorporating video microscopy so the patient can choose to watch the procedure at the same time.

5. Conclusion

Composite cartilage-perichondrium graft myringoplasty in a palisade fashion under local anesthetic is a feasible and highly successful procedure that can be applied to adult and pediatric patients with variable perforation sizes. It has a moderate learning curve given the use of a transcanal approach in an awake patient. The procedure offers many benefits to the patient, and is associated with a low rate of complications. Future studies may include a cost analysis to evaluate potential savings to the health care system.

References

- [1] Zollner F. The principles of plastic surgery of the sound-conducting apparatus. *J Laryngol Otol* 1955;69(10):637–52.

- [2] Wullstein H. Theory and practice of tympanoplasty. *Laryngoscope* 1956;66(8):1076–93.
- [3] Boedts D. Tympanic grafting materials. *Acta Otorhinolaryngol Belg* 1995;49(2):193–9.
- [4] Kazikdas KC, Onal K, Boyraz I, Karabulut E. Palisade cartilage tympanoplasty for management of subtotal perforations: a comparison with the temporalis fascia technique. *Eur Arch Otorhinolaryngol* 2007;264(9):985–9.
- [5] Indorewala S. Dimensional stability of free fascia grafts: clinical application. *Laryngoscope* 2005;115(2):278–82.
- [6] Onal K, Arslanoglu S, Songu M, Demiray U, Demirpehlivan IA. Functional results of temporalis fascia versus cartilage tympanoplasty in patients with bilateral chronic otitis media. *J Laryngol Otol* 2012;126(1):22–5.
- [7] Dornhoffer JL. Surgical management of the atelectatic ear. *Am J Otol* 2000;21(3):315–21.
- [8] Ozbek C, Ciftci O, Ozdem C. Long-term anatomic and functional results of cartilage tympanoplasty in atelectatic ears. *Eur Arch Otorhinolaryngol* 2010;267(4):507–13.
- [9] Uzun C, Caye-Thomassen P, Andersen J, Tos M. A tympanometric comparison of tympanoplasty with cartilage palisades or fascia after surgery for tensa cholesteatoma in children. *Laryngoscope* 2003;113(10):1751–7.
- [10] Anderson J, Caye-Thomassen P, Tos M. A comparison of cartilage palisades and fascia in tympanoplasty after surgery for sinus or tensa retraction cholesteatoma in children. *Otol Neurotol* 2004;25(6):856–63.
- [11] Gross CW, Bassila M, Lazar RH, Long TE, Stagner S. Adipose plug myringoplasty: an alternative to formal myringoplasty techniques in children. *Otolaryngol Head Neck Surg* 1989;101(6):617–20.
- [12] Saliba I, Woods O. Hyaluronic acid fat graft myringoplasty: a minimally invasive technique. *Laryngoscope* 2011;121(2):375–80.
- [13] Laidlaw DW, Costantino PD, Govindaraj S, Hiltzik DH, Catalano PJ. Tympanic membrane repair with a dermal allograft. *Laryngoscope* 2001;111(4 Pt 1):702–7.
- [14] Eavey RD. Inlay tympanoplasty: cartilage butterfly technique. *Laryngoscope* 1998;108(5):657–61.
- [15] Lubianca-Neto JF. Inlay butterfly cartilage tympanoplasty (Eavey technique) modified for adults. *Otolaryngol Head Neck Surg* 2000;123(4):492–4.
- [16] Haksever M, Akduman D, Solmaz F, Gundogdu E. Inlay butterfly cartilage tympanoplasty in the treatment of dry central perforated chronic otitis media as an effective and time-saving procedure. *Eur Arch Otorhinolaryngol* 2015;272(4):867–72.
- [17] Saliba I. Hyaluronic acid fat graft myringoplasty: how we do it. *Clin Otolaryngol* 2008;33(6):610–4.
- [18] Jansen C. Cartilage—tympanoplasty. *Laryngoscope* 1963;73:1288–301.
- [19] Salen B. Myringoplasty using septum cartilage. *Acta Otolaryngol Suppl* 1964;188(SUPPL):188. [182+].
- [20] Jalali MM, Motasaddi M, Kouhi A, Babiri S, Soleimani R. Comparison of cartilage with temporalis fascia tympanoplasty: a meta-analysis of comparative studies. *Laryngoscope* 2017;127(9):2139–48.
- [21] Mohamad SH, Khan I, Hussain SS. Is cartilage tympanoplasty more effective than fascia tympanoplasty? A systematic review. *Otol Neurotol* 2012;33(5):699–705.
- [22] Vashishth A, Mathur NN, Choudhary SR, Bhardwaj A. Clinical advantages of cartilage palisades over temporalis fascia in type I tympanoplasty. *Auris Nasus Larynx* 2014;41(5):422–7.
- [23] Collins WO, Telischi FF, Balkany TJ, Buchman CA. Pediatric tympanoplasty: effect of contralateral ear status on outcomes. *Arch Otolaryngol Head Neck Surg* 2003;129(6):646–51.
- [24] Onal K, Uguz MZ, Kazikdas KC, Gursoy ST, Gokce H. A multivariate analysis of otological, surgical and patient-related factors in determining success in myringoplasty. *Clin Otolaryngol* 2005;30(2):115–20.
- [25] Adkins WY, White B. Type I tympanoplasty: influencing factors. *Laryngoscope* 1984;94(7):916–8.
- [26] Murbe D, Zahner T, Bornitz M, Huttenbrink KB. Acoustic properties of different cartilage reconstruction techniques of the tympanic membrane. *Laryngoscope* 2002;112(10):1769–76.
- [27] Lee CF, Chen JH, Chou YF, Hsu LP, Chen PR, Liu TC. Optimal graft thickness for different sizes of tympanic membrane perforation in cartilage myringoplasty: a finite element analysis. *Laryngoscope* 2007;117(4):725–30.
- [28] Gerber MJ, Mason JC, Lambert PR. Hearing results after primary cartilage tympanoplasty. *Laryngoscope* 2000;110(12):1994–9.
- [29] Ghanem MA, Monroy A, Alizade FS, Nicolau Y, Eavey RD. Butterfly cartilage graft inlay tympanoplasty for large perforations. *Laryngoscope* 2006;116(10):1813–6.
- [30] Roger G, Bokowy C, Coste A, et al. Tympanoplasty using chondro-perichondral graft. Indications, techniques and results. Apropos of a series of 127 cases. *Ann Otolaryngol Chir Cervicofac* 1994;111(1):29–34.
- [31] Iacovou E, Vlastarakos PV, Papacharalampou G, Kyrodimos E, Nikolopoulos TP. Is cartilage better than temporalis muscle fascia in type I tympanoplasty? Implications for current surgical practice. *Eur Arch Otorhinolaryngol* 2013;270(11):2803–13.
- [32] Cavaliere M, Mottola G, Rondinelli M, Iemma M. Tragal cartilage in tympanoplasty: anatomic and functional results in 306 cases. *Acta Otorhinolaryngol Ital* 2009;29(1):27–32.
- [33] Zahner T, Huttenbrink KB, Murbe D, Bornitz M. Experimental investigations of the use of cartilage in tympanic membrane reconstruction. *Am J Otol* 2000;21(3):322–8.
- [34] Davidson M. A study of the fate of autogenous cartilage grafts. *Laryngoscope* 1959;69:1259–77.
- [35] Simmons FB, Glatke TJ, Downie DB. Lidocaine in the middle ear. A unique cause of vertigo. *Arch Otolaryngol* 1973;98(1):42–3.