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The Role of Obliteration in the Achievement of a Dry Mastoid Bowl

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Abstract

Objective—To evaluate the impact of mastoid obliteration on the achievement of a dry mastoid bowl and frequency of maintenance care.

Study Design—Retrospective chart review.

Setting—Academic medical center.

Patients—There were 63 canal-wall-down mastoidectomies for chronic otitis media with or without cholesteatoma between 2007 and 2014 with follow-up of at least 6 months. Eighteen mastoids were nonobliterated and 45 were obliterated. Thirteen underwent secondary obliteration of existing mastoid bowls with chronic drainage, whereas 32 underwent primary obliteration at the original canal-wall-down procedure.

Intervention—Mastoid obliteration.

Main Outcome Measures—Achievement of a dry healed mastoid cavity and frequency of outpatient visits.

Results—In more than 80% of the cases, a dry ear was achieved, with no significant difference between the obliterated and nonobliterated cases ($p = 0.786$). Eleven of the 13 secondary cases experienced cessation of otorrhea, achieving dry ears at rates similar to that of the primary and nonobliterated cases. The secondary obliteration population was also significantly younger than the primary group (22.1 versus 43.5 years, $p = 0.002$). Multivariable-mixed effects analysis demonstrated a reduction in 0.1 visits per 6-month period following surgery overtime ($p < 0.001$).

Conclusions—Mastoid obliteration may be valuable in the management of the well-developed and chronically wet mastoid cavity, particularly when the drainage emanates from mucosal disease or cell tracts in a deep sinodural angle. Younger patients may require secondary obliteration because of continued craniofacial maturation several years following canal-wall-down surgery.

Keywords

Canal wall down mastoidectomy; Chronic ear disease; Mastoid obliteration

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The primary goal of surgical intervention for chronic ear disease is the development of a safe, dry, and low-maintenance ear (1,2). Exteriorization of attic and mastoid disease with a canal-wall-down mastoidectomy has a high rate of success in achieving a safe ear (1), but there is a need for continuous care including a high incidence of moisture resulting in drainage or crusting (3). Persistent moisture, infection, and drainage is problematic in as many as one-third of patients requiring revision surgery following canal-wall-down mastoidectomy (3), which may be attributed to mucosalized surfaces, persistent cell tracts, or poorly ventilated areas opening into the mastoid bowl (2). Despite careful observation of best practices including mastoid saucerization, removal of the mastoid tip, lowering of the facial ridge, and creation of an adequately sized meatus (4), moisture may persist in areas of the mastoid bowl leading to stasis of mucoid exudates, localized areas of infection, and underlying mucosal changes.

Open mastoid procedures have been criticized for the unfavorable cosmetic appearance of a large meatoplasty, the perpetual need for intermittent cleaning, as well as the propensity for chronic moisture and intermittent super-infection or drainage (2,5). These concerns have led some to primarily advocate for the use of canal-wall-up mastoidectomies (4), or propose the reconstruction of the ear canal-mastoid partition (6) or obliteration of the mastoid cavity (2,7-9).

Mastoid obliteration has gained increasing attention as an adjunct to open mastoid procedures (2,9). Obliteration can be performed using a variety of techniques or materials, including but not limited to autologous bone chips and dust (10), hydroxyapatite (11,12), cartilage (13), and periosteal-pericranial flaps (8). Mastoid obliteration has been proposed to facilitate healing and epithelialization (8,9), and can be performed at the original canal-wall-down procedure or in a delayed secondary procedure after the canal wall is taken down (9). Obliteration reduces the volume of the mastoid cavity (2,9), thereby reducing the meatal size needed for effective clinic management. A reduction of mastoid recess depth and overall volume may also eliminate areas of chronic moisture (2,8), theoretically reducing the frequency of needed cleaning.

The need for frequent clinic follow-up has been reported for canal-wall-down mastoidectomy (3,5), and is a significant source of frustration and resource burden to individuals and the health system. We review our experience of surgical outcomes of canal-wall-down mastoidectomy with and without obliteration for the management of chronic ear disease, with particular attention to the establishment of a dry, low-maintenance ear, and the frequency of outpatient clinic follow-up. We compare outcomes between obliterated versus nonobliterated mastoid bowls, as well as the impact of primary versus secondary obliteration.

METHODS

A retrospective chart review was conducted for patients who underwent canal-wall-down mastoidectomy for chronic otitis media with or without cholesteatoma between January 1, 2007 and June 30, 2014 with at least 6 months of postoperative outpatient follow-up. The hospital institutional review board approved this study.

Study Population

A query was conducted for all surgical encounters and outpatient visits associated with the procedure code for canal-wall-down mastoidectomy between January 1, 2007 and June 30, 2014 for the treatment of chronic otitis media with and without cholesteatoma in patients of the senior author (H.W.F.). Procedures performed by a single individual were chosen to eliminate intersurgeon variability in surgical technique. The patients must have had at least one postoperative visit documented and at least 6 months of postoperative out-patient follow-up. Patients were excluded if their follow-up was less than 6 months and if the indication for surgery was for disease other than cholesteatoma or chronic otitis media.

Surgical Technique

All patients underwent modified radical mastoidectomy (MRM) with or without obliteration, with the exception of one patient who underwent a radical mastoidectomy with removal of the tympanic membrane. A pericranial flap was utilized in most cases in an obliteration technique similar to that reported by Ramsey et al. (8). A temporal parieto-fascial flap was utilized in other cases (14,15). Autologous bone dust was collected and placed in areas of deep pockets or previous drainage, with care not to bury keratinized epithelium. The flap was then draped over the packed bone paté. In some cases, the periosteal or temporal parieto-fascial flap was directly placed on to native bone within the mastoid bowl without bone paté. Figure 1 shows obliteration of a left mastoid cavity.

Variables and Outcomes

Medical records were reviewed to extract demographic information, including characteristics of ear disease, tobacco use, history of previous surgical interventions, history of tympanostomy tube placement, surgical technique and observations, and the number of outpatient clinic visits. The main outcomes of interest were achievement of a dry ear, time to development of a dry ear, and mean number of outpatient clinic visits per 6-month period. A dry ear was defined as a well-epithelialized mastoid cavity with the absence of drainage, moisture, mucous, or granulation tissue that remained stable for two or more clinic visits. The number of outpatient clinic visits for the 6 months preceding surgery was collected. The number of postoperative outpatient clinic visits per 6-month interval up to 4 years was collected (i.e., number of visits for 0–6 months, 6–12 months, 12–18 months, 18–24 months, 24–30 months, 30–36 months, 36–42 months, and 42–48 months time periods postsurgery). The outpatient clinic visits included the total number of regularly scheduled visits and patient-initiated visits for any mastoid bowl health concerns. The main independent variables of interest were age, sex, tobacco use, history of previous surgical intervention in the same ear, history of tympanostomy tube placement, and surgical technique. Tobacco use was defined as current tobacco use. Surgical technique was classified as canal-wall-down mastoidectomy with obliteration (hereafter referred to as “obliterated”) and canal-wall-down mastoidectomy without obliteration (hereafter referred to as “non-obliterated”). Obliterated surgeries were then further subdivided into primary (obliteration surgery performed at the time of canal-wall-down surgery) or secondary (obliteration surgery performed following previous canal-wall-down surgery) cases, with or without bone dust.

Statistical Analysis

Data were initially analyzed using bivariate analyses to compare the variables of interest between obliterated and nonobliterated ears. Categorical variables (sex, dry ear, history of previous interventions, tobacco use, and history of tympanostomy tube placement) were tested using a χ^2 statistic. Continuous variables (mean age and mean time to dry ear) were tested using independent sample t tests. Obliterated patients were further stratified into primary and secondary obliteration groups. The association of categorical and continuous variables with primary versus secondary obliteration status was tested with the χ^2 statistic or t test, respectively. Multivariable-mixed effects regressions adjusted for age, sex, tobacco use, obliteration surgery, and timing of surgery were used to analyze the association between time of follow-up and change in frequency of visits from baseline. These regressions include both fixed and random-effects terms, and are particularly useful when applied in settings where repeated measurements are made on the same statistical units—as in our case when data are gathered overtime on the same individuals (16). All statistical analyses were conducted with Stata version 13 (College Station, TX, U.S.A).

RESULTS

Patient Characteristics

There were 63 cases for 60 patients that met the inclusion criteria. The mean outpatient postsurgical follow-up length was 30.5 months (standard deviation [SD] 23.2 months). All but one surgery resulted in MRMs with covered mesotympanum. One patient had a primary obliteration canal-wall-down mastoidectomy performed on both ears. One patient had a failed primary obliteration surgery, followed by a secondary obliteration surgery performed on the same ear. One patient had two secondary obliteration surgeries performed on the same ear. There were no significant differences in the time to achievement of a dry ear or mean number of pre- or postoperative outpatient visits amongst the groups.

Comparison of Mastoid Bowl Outcomes in Obliterated Versus Nonobliterated Ears

Patient characteristics and mastoid bowl health relative to obliteration status are presented in Table 1. Of the 63 mastoidectomy procedures, there were 45 cases with obliteration and 18 cases without obliteration. The proportion of canal-wall-down mastoidectomies that resulted in a dry ear within 6 months was similar for the obliterated (71.1%) and the nonobliterated (77.8%) cases ($p = 0.590$). Eventually a dry ear was achieved by 91.1% and 88.9% of the obliterated and nonobliterated cases, respectively ($p = 0.786$). There was no significant difference in age, sex, tobacco use, history of previous surgical intervention, or history of tympanostomy tube placement between the two groups.

Two (11.1%) of the nonobliterated cases compared with seven (15.6%) of the obliterated cases had postoperative complications, but there were no significant differences between the groups ($p = 0.649$). Both of the nonobliterated cases developed mastoid bowl infections requiring antibiotic treatment. Three (4.7%) of the obliterated cases developed stenosis or scarring of the meatoplasty. Two cases (3.2%) developed postauricular wound infections. One case (1.6%) developed partial necrosis of the pericranial flap. One case (1.6%)

developed recurrent cholesteatoma and underwent revision mastoidectomy and obliteration surgery.

Comparison of Mastoid Bowl Outcomes Following Primary Versus Secondary Obliteration

Patient characteristics and time to dry mastoid bowl are presented by primary versus secondary obliteration status in Table 2. There were 32 primary obliterations and 13 secondary obliterations. Those patients who underwent secondary obliteration were significantly younger at the time of surgery (mean age 22.1 versus 43.5 years, $p = 0.002$). They were even younger at the time of their primary canal-wall-down mastoidectomy (mean age 10.4 years, SD 8.4 years). The secondary oblitative patients all underwent previous surgical intervention in the same ear compared with only 43.8% of the primary oblitative group ($p < 0.001$). There was no significant difference in the proportion of cases that achieved a dry ear at 6 months (75.0% of primary ears versus 61.5% of secondary ears, $p = 0.367$). Similarly, there was no significant difference in the proportion that eventually achieved a dry ear (93.8% of the primary ears versus 84.6% of the secondary ears, $p = 0.329$). There was no significant difference in tobacco use and history of tympanostomy tube placement.

Frequency of Outpatient Clinic Visits

Overall, the mean number of postoperative outpatient clinic visits for all patients was 9.8 (SD 4.7) visits. The mean number of postoperative outpatient clinic visits for obliterated and nonobliterated patients overtime is presented in Figure 2. There is a sharp decline in the number of visits after the first 6 months, after which there is a steady decline overtime.

The change in frequency of outpatient visits from baseline is presented in Table 3. Multivariable-mixed effects analysis, adjusted for age and sex, demonstrates a significant impact by time of follow-up on the reduction in outpatient visits from baseline, with a decline of 0.1 visits per 6-month period following surgery ($p < 0.001$). Patients undergoing obliteration surgery demonstrated a 0.81 decline in number of visits per 6-month follow-up period, while those undergoing a primary obliteration compared with secondary procedure had an increase of 1.15 visits per 6-month follow-up period as compared with the baseline. However, neither of these trends achieved statistical significance at a p value of 0.092 and 0.076, respectively.

Description of Secondary Obliterated Cases

The characteristics of the 13 secondary obliterated cases are presented in Table 4. One patient had missing information on age at first canal-wall-down surgery. For the remaining patients, the mean age at first surgery was 10.4 years (SD 8.4 years), with 11 of 12 individuals having surgery at 13 years or younger. Seventy seven percent of the secondary cases were male compared with 65.6% of the primary cases and 55.6% of the nonobliterated cases. Seven secondary obliteration cases (53.8%) had chronic drainage at the sinodural angle, and two cases (15.4%) had chronic drainage secondary to cholesteatoma. Eleven ears (84.6%) had cessation of drainage at the site of their chronic drainage and achieved a dry mastoid cavity.

DISCUSSION

In our retrospective review, we found that the majority of individuals undergoing mastoid surgery with or without obliteration achieved a dry ear and there was a reduction of clinic visits overtime. This study was unable to definitively demonstrate a clear advantage of primary obliteration in the achievement of either a dry ear or decrements in the frequency of follow-up. Following secondary obliteration surgery for chronically wet draining mastoid bowls, however, individuals achieved a dry ear in over 80% of cases. An unexpected finding was the association between younger age and persistently wet mastoid bowl requiring secondary obliteration. The majority of the secondary cases were also male.

This study highlights the outpatient follow-up burden of those undergoing canal-wall-down mastoidectomy. Removal of the posterior external auditory canal necessitates regular visits for the maintenance of the mastoid bowl, as underscored in a recent review of postoperative visits following MRM (5). The authors reported an average of over eight visits per person over a median follow-up time of almost 4 years, with the greatest number of visits in the first 2 years after surgery (5). Although we found no significant difference in functional outcomes in the obliterated versus nonobliterated mastoids, there was trend toward the reduction of outpatient visits in the obliterated group (although this result was only borderline significant). A reduction in clinic visits that obliteration may provide, therefore, could help reduce the burden on both the patient and the provider. Fewer patient visits may also lead to a decrease in healthcare expenditures, which has become a priority as United States healthcare costs are projected to rise (17).

In this study, primary obliteration of the mastoid does not appear to offer a significant added benefit to the likelihood of achieving a dry ear, including no reduction in the subsequent frequency of needed clinic visits. More than half of the primary obliteration cases were performed in a surgery-naïve ear, whereas by definition, all of the secondary cases had at least one previous surgical intervention. The primary obliteration cases are generally referred from outside the institution, whereas the secondary group has been followed more closely overtime and therefore more data are available. A larger sample size and more longitudinal data may be needed to adequately compare the two groups.

Secondary obliteration of an existing canal-wall-down mastoid cavity may be a useful intervention to address the chronically draining mastoid bowl (2,7,9,18), particularly when emanating from sinodural and postsigmoid recesses and cell tracts of a well-developed mastoid (2). The majority of our secondary obliterated patients experienced the cessation of drainage within 6-months postintervention (although one patient required an additional obliteration procedure). These results are similar to what has been previously reported. One study randomized individuals with persistent chronic suppurative otitis media after MRM to either secondary obliteration or conservative medical management (18). They found a cessation of drainage in over 90% of obliterated patients compared with only 10% of control patients at 6 months, suggesting the efficacy of secondary obliteration in addressing their disease. Secondary obliteration has also been found to improve the quality of life for individuals postintervention as compared with primary obliterated patients (7), demonstrating its critical role beyond addressing physical outcomes.

The most common site of drainage in our secondary obliteration population was a deep recess of the sinodural angle, which has been identified as a frequent area of remucosalization of persistent air cells (2). The sinodural angle, therefore, requires careful attention at the initial procedure in an attempt to obviate additional interventions. As this can be difficult to prevent in the extensively pneumatized adult mastoid, primary obliteration in these cases may be a useful strategy. This study did not stratify patients by the extent of preoperative pneumatization, however, which is required to answer this question. It is likely however that adults requiring secondary obliteration for chronically draining mastoid bowls may have fit into this category as standard management of the mastoid was first exhausted without success in this group.

We also found that most of the secondary obliterated patients underwent their original canal-wall-mastoidectomy surgery in the prepubescent period. The Eustachian tube in infants and young children is positioned more horizontally than in older children and adults (19), which may predispose the young to development of chronic ear disease. Eustachian tube obstruction because of adenoid hypertrophy and allergic rhinitis has also been linked to younger age (20), which may increase the risk of otitis media. Although information on Eustachian tube dysfunction was not available, we did have information on history of previous tympanostomy tube placement, which could be reflective of Eustachian dysfunction. However, we found no significant difference between the primary and secondary obliterated groups.

Another possible cause for the additional interventions in younger individuals is their continued craniofacial maturation, including progressive pneumatization their mastoid air cells. A recent study found a steady age-dependent linear growth of mastoid air cells on computed tomography imaging in a cross-sectional group of individuals aged 1 to 18 years (21). Another study found a steady linear growth up to age 6, followed by a slower increase in volume to adolescence (22). Continued mastoid pneumatization occurring after primary obliteration procedures may contribute to recurrent disease, necessitating additional interventions to achieve a dry mastoid cavity. This should be taken into account when counseling patients and their families about the risks of the procedure for pediatric populations. It may also be wise to delay any secondary obliteration procedure until the completion of this pneumatization process.

Interestingly, the majority of the secondary cases were male. A greater proportion of otitis media have been reported in male children (23), and in one retrospective review of chronic otitis media in infants, males were twice as likely to develop the disease compared with females (24). We would therefore hypothesize males would have larger cavities in the pediatric population because of increased need for aural hygiene necessitating secondary oblitative procedures. In one retrospective review of computed tomographic scans from healthy subjects, males had on average larger volumes of mastoid pneumatization than females in the first two decades (25), potentially supporting our hypothesis. They found, however, that the rate of increase in pneumatization was more rapid in females (25). Another study found that females had slightly larger surface area to volume ratios than males (although this was not statistically significant) (21). Similarly, the mastoid air cell system has been found to be most often larger in females until puberty in another

investigation (22). Sex differences in cavity size and pneumatization and their association with the chronically draining mastoid, therefore, warrant further investigation.

The extent to which other risk factors for continued mastoid disease affected our patient population is not known. Tobacco use has been found to increase the risk of middle ear disease (23), possibly because of ciliary dysfunction (26). However, we found no significant difference in tobacco use between the groups, possibly because of small sample size. Additionally, potential genetic loci controlling the susceptibility to otitis media have been identified (27), but genetic history and testing was not readily available in our population. In addition, information on socioeconomic status (SES) would also be of interest, as low SES has been identified as a risk factor for chronic ear disease (23,28). Presenting the functional outcomes by SES may have proved informative.

This study does have several limitations. A retrospective review is limited to what is available in the patients' medical record, which may have had errors or omissions. The retrospective nature of this study does not allow us to determine causal relationships, but rather hypothesize about associations between variables. In addition, we included patients who were operated on by one provider and had follow-up within the Department of Otolaryngology-Head and Neck Surgery at our institution. Those individuals who opted to follow-up elsewhere were excluded from the current study. Therefore, our sample may not completely represent our target population. Our subgroup analysis sample sizes may not have been significantly powered to allow for the determination of statistically significant results. We also used a more strict definition of a dry mastoid cavity, in which there was an absence of drainage, moisture, mucous, or granulation tissue. Grading systems to assess varying degrees of moisture of the mastoid cavity have been used by others (8). We were primarily interested in the achievement of a completely dry ear, however, which in some individual cases did not occur. Additionally, outpatient clinic visits included both regularly scheduled and patient-initiated visits. Patient-initiated visits are often as a result of new or worsening symptoms (e.g., increased otorrhea) and are more likely to reflect surgical outcomes as compared with prospectively scheduled appointments. However, these visit types could not be distinguished in this retrospective study. Lastly, reductions in clinic visit frequency compared with baseline may be underestimated because of the limited number of preoperative visits in a patient population that is predominantly referred.

Mastoid obliteration may be valuable in the management of the chronically wet cavity related to a deep posterior recess or sinodural angle, particularly in well-developed mastoids. Craniofacial maturation may continue in the pediatric population several years following canal-wall-down surgery, which may lead to the development of difficult to manage mastoid bowls and warrants further investigation.

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FIG. 1. Obliteration of a left mastoid cavity. *A*, Packing of bone pate. *B*, Draping of inferior-based temporoparietal flap. *C*, Shallow and dry sinodural angle.

FIG. 2.

Mean number of postoperative outpatient visits over time for the obliterated and nonobliterated cases.

TABLE 1
Outcomes of obliterated versus nonobliterated cases

Subject Variables and Outcomes	Group		Test Statistic (<i>p</i> Value)
	Nonobliterated n = 18 (n/%)	Obliterated n = 45 (n/%)	
Mean age in years (SD)	41.8 (20.2)	37.3 (21.3)	0.441
Sex			
Male	10 (55.6%)	31 (68.9%)	0.316
Female	8 (44.4%)	14 (31.1%)	
Previous surgical intervention			
Yes	5 (27.8%)	18 (40.0%)	0.363
No	13 (72.2%)	27 (60.0%)	
Tobacco exposure			
Yes	3 (16.7%)	3 (6.7%)	0.222
No	15 (83.3%)	42 (93.3%)	
Previous tympanostomy tubes			
Yes	10 (55.6%)	17 (37.8%)	0.198
No	8 (44.4%)	28 (62.2%)	
Mean time to dry ear in weeks (SD)	21.0 (14.3)	18.6 (13.0)	0.538
Dry ear by 6 months			
Yes	14 (77.8%)	32 (71.1%)	0.590
No	4 (22.2%)	13 (28.9%)	
Dry ear at any time			
Yes	16 (88.9%)	41 (91.1%)	0.786
No	2 (11.1%)	4 (8.9%)	
Postop complications			
Yes	2 (11.1%)	7 (15.6%)	0.649
No	16 (88.9%)	38 (84.4%)	

SD indicates standard deviation.

TABLE 2
Outcomes of primary versus secondary obliteration cases

Subject Variables and Outcomes	Group		Test Statistic (<i>p</i> Value)
	Primary n = 32 (n/%)	Secondary n = 13 (n/%)	
Mean age in years (SD) at time of surgery	43.5 (21.1)	22.1 (13.0)	0.002
Sex			
Male	21 (65.6%)	10 (76.9%)	0.458
Female	11 (34.4%)	3 (23.1%)	
Previous surgical intervention			
Yes	14 (43.8%)	13 (100%)	<0.001
No	18 (56.2%)	0 (0%)	
Tobacco exposure			
Yes	3 (9.4%)	0 (0%)	0.253
No	29 (90.6%)	13 (100 %)	
Previous tympanostomy tubes			
Yes	11 (34.4%)	6 (46.2%)	0.460
No	21(65.6%)	7 (53.9%)	
Mean time to dry ear in weeks (SD)	18.2 (11.9)	19.6 (16.3)	0.753
Dry ear by 6 months			
Yes	24 (75.0%)	8 (61.5%)	0.367
No	8 (25.0%)	5 (38.5%)	
Dry ear at any time			
Yes	30 (93.8%)	11 (84.6%)	0.329
No	2 (6.2%)	2 (15.4%)	

SD indicates standard deviation.

TABLE 3
Multivariable mixed effects models of change in frequency of outpatient visits from baseline per 6-month period

Models	Change From Baseline Frequency of Visits	
	Coefficient (SE)	<i>p</i> Value
Model 1 ^a		
Month ^b	−0.10 (0.01)	<0.0001
Obliterated ^c	−0.81 (0.46)	0.092
Model 2 ^a		
Month ^b	−0.10 (0.01)	<0.0001
Primary ^d	1.15 (0.65)	0.076

^a Adjusted for age, sex, and tobacco exposure.

^b Time of follow-up measured from baseline to 48 months after surgery in 6-month increments.

^c Obliterated versus nonobliterated.

^d Primary obliterated versus secondary obliterated.

TABLE 4

Descriptions of secondary obliteration cases

Case No.	Age	Age at First CWD	Sex	Source of Drainage	Obliteration Type	Postop Complications	Mean Preop Visits ^a	Mean Postop Visits ^a	Did Drainage Stop? ^a	Time to Dry Ear (weeks)
1	31	Unknown	M	Antrum cholesteatoma	PF	N	3.0	4.0	Y	8
2	26	10	M	Granulation tissue at posterior recess of the sinodural angle	PF + BD	N	7.0	2.8	Y	5
3	14	11	M	Granulation tissue in deep crevice between tegmen and lateral semicircular canal	PF + BD	N	3.0	1.5	Y	61
4	7	3	M	Retained debris at sinodural angle with bony overhang creating deep cell tract	PF + BD	N	2.0	1.8	Y	8
5	32	13	M	Mucous from deep recess of the sinodural angle	PF + BD	N	4.0	3.0	Y	12
6	26	9	M	Retained debris within deep posterior recess of the mastoid bowl	PF + BD	Y ^b	3.0	2.0	Y	17
7	7	3	M	Retained debris in deep sinodural angle	PF + BD	N	2.0	1.6	Y	8
8 ^c	12	4	M	Retained debris in deep sinodural angle	PF + BD	Y ^d	1.0	4.0	N	Persistent until surgery
9 ^c	13	4	M	Retained debris and cholesteatoma in deep sinodural angle	PF + BD	N	2.0	7.0	Y	16
10	14	11	M	Retained debris deep in sinodural angle	PF + BD	N	3.0	2.0	Y	4
11	42	34	F	Cholesteatoma beyond residual canal from previous CWD surgery	PF + BD	N	1.0	6.0	N	Persistent at 7 months ^e
12	16	10	F	Granulation tissue within the attic and persistent mastoid tip air cell	PF	N	1.0	2.0	Y	12
13	47	13	F	Mucosalization in the posterior recess of the mastoid beyond high facial ridge	PF + BD	Y ^f	1.0	1.2	Y	19

BD indicates bone dust; CWD, canal wall down mastoidectomy; F, female; M, male; N, no; PF, pericranial flap; Y, yes.

^aMean number of visits per 6-month period.

^bInfection caused by retained stitch.

^cThese are the same patients in the same ear. Two obliteration surgeries performed 1 year apart.

^dPersistent drainage 10 months after initial obliteration surgery, later found to have recurrent cholesteatoma.

^eLost to follow-up after 7 months.

^fPartial necrosis of pericranial flap.