The effect of external auditory canal reconstruction with mastoid obliteration after canal wall down tympanomastoidectomy on hearing function: narrative review and case series.

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Abstract: This study evaluates the impact of mastoid obliteration (MO) on hearing outcomes and ear anatomy following canal wall-down (CWD) tympanoplasty. MO, performed with autologous or homologous materials, aims to restore the external ear canal (EEC) volume and improve postoperative quality of life by reducing heat sensitivity, water exposure, and infection risk. A case series of patients undergoing CWD with simultaneous MO was analyzed, measuring EEC volume (ECV), pure tone audiometry (PTA), and subjective hearing via the Speech, Spatial and Qualities of Hearing Scale (SSQ). Results showed that MO effectively restored ECV within normal ranges, regardless of the obliteration material used, and PTA outcomes indicated good hearing thresholds (≤30 dB). Subjectively, patients reported better hearing experiences, with SSQ scores comparable to or exceeding those of a control population. Literature review corroborates that CWD procedures alter ear acoustics, but MO can reverse these effects, improving sound transmission and perception. Overall, MO with autologous or homologous materials is a safe, effective technique for reconstructing ear anatomy, optimizing hearing outcomes, and enhancing patient-reported hearing quality post-surgery.

Keywords: Mastoid Obliteration, external ear canal reconstruction, bone allograft, homologous graft, ear surgery

Introduction

The mastoid obliteration (MO) is a reconstructive surgical procedure that can reshape a normal anatomy of the external ear canal (EEC) after a mastoidectomy that involves the bony walls of the ear canal. MO can be performed with different materials, which are used to fill the surgical cavity. The technique provides several advantages which can mitigate side effects experienced by patients who receive a canal wall-down tympanoplasty (CWD) (Guilford, 1961; Hartwein, 1990; Pou, 1977), such as ear sensibility to heat and water and the need for frequent medical evaluations. Furthermore, it lowers the risk of infections and chronic otorrhea. Recently, the introduction of non-surgical follow-up of patients with chronic otitis media with cholesteatoma (COMC) with non-EPI DWI Magnetic Resonance Imaging sequences has allowed the surgeons to perform a one-time surgery and MO can be performed without troubles due to the necessity of a second look surgery.

The anatomy of the ear has specific features that help to transmit the sound energy to the internal ear. The CWD technique modifies the shape of the external and middle ear, and possibly changes the capability of the ear of sound transmission (Prodanovic, 2020; Jang, 2002; McElveen, 1982; Browning, 1984).

Few studies have concentrated on the effect of MO on hearing outcomes and sound transmission. To the best of our knowledge, the present review reports what is available in the literature on this topic. In addition, we present a case series of patients who underwent CWD procedures with simultaneous MO in ENT dept. of Hospital of Cittadella, Veneto, Italy. The goal is to investigate the effects of the MO with two different types of obliterative material on the anatomical results (volume of the external ear ear canal -ECV-), the postoperative hearing results with objective (pure tone average -PTA-) and subjective analysis (answers to the speech, spatial and qualities of hearing scale questionnaire -SSQ-).

Materials and methods

A group of patients who received a MO after CWD tympanoplasty in ENT dept. of Cittadella Hospital was retrieved. We collected surgical information relative to the mastoid obliteration (type of material used). With an impedance machine the external canal volume (ECV) was measured at 12 months after surgery. The postoperative hearing was tested with pure tone audiometry at 12 months after surgery and pure tone average (PTA) was reported.

The inclusion criteria for this study included: (i) patients undergone CWD tympanopplasty with MO; (ii) PTA of 40 dB or better in the non-operated ear; (ii) PTA of 50 dB or better he operated ear; (iii) age over 17 years

PTA was calculated in the average of frequencies 500, 1000, 2000 e 4000 hz. ECV is measured in ml, with a reported normal range of 0.6- 2.50 ml.

MO was performed with two types of material, autologous and homologous. Based on the material used for MO, patients were divided into two groups. The autologous material, called bone paté, was obtained by drilling the mastoid cortex during the CWD technique. The homologous bone used was obtained from corticoncellous freeze-dried bone, provided by a human tissue bank. The MO with homologous bone was described in an original form in a previous work (cit.) and called 'cupeta tecnique'.

A subjective hearing analysis, the SSQ questionnaire, was collected 12 months after surgery. SSQ was proposed according to the original paper by Gatehouse and Noble in 2004 (Gatehouse, 2004). The questionnaire indicates hearing disability assessment, identifying three general domains: speech, spatial and 'other qualities' of hearing. 14 scored items-questions on speech hearing, 17 on spatial hearing, and 18 on the other functions and qualities listed above are included. In the original paper of Gatehouse et al (Gatehouse, 2004), the averages of the results were reported for each single question. For our group, we elaborated an average of the answers for each patient and for each of the three areas.

We subsequently divided our sample into two groups, depending on the type of mastoid obliteration material (Allogenic/allograft and autologous material). We first performed a descriptive analysis of the samples; then we tested the differences between the two groups using the Mann-Whitney U test, analysing the ECV, the PTA in both ears and the age. using R(R Core Team, 2023). The results of SSQ questionnaire in the three domains were compared, as a control group, to the patients of Gatehouse and Noble study. This control group were 153 people in the sample, with the better-ear PTA was 38.8 dB (SD 15.5); the worse-ear average PTA was 52.7 dB (SD 24.4). As for our group, we elaborated an overall average of the patients' answers for each of the areas of the questionnaire, in order to be able to compare the results.

Review of literature was obtained focusing on the topics of MO and quality of hearing. Two databases, PubMed and Scopus were systematically screened up to 12/03/2025 using the following free term search: "mastoid obliteration" and a combination of the terms "sound", "transmission", and "hearing function". All the retrieved publications were screened and then evaluated to identify the most relevant ones. Duplications or aggregations of pre-existing data were excluded. No time or language limits were applied. The reference lists of selected articles were also analysed to identify additional studies.

Results

The results of our analysis are reported in table 1. In figure 1, we report the distribution of the variables in the sample we analysed.

Table 1. Description of the sample.

	age	ecv	pta	pta_healthy_side	ssq_speech	ssq_spatial	ssq_qualities
Mean	37.5	1.96	26.6	17.1	7.92	7.52	8.09
Median	42.0	1.70	25.0	13.0	8.50	7.70	8.50
Standard deviation	13.2	0.674	10.6	8.70	1.64	1.49	1.60
Minimum	17.0	1.20	11.0	10.0	5.50	5.81	5.61
Maximum	57.0	3.20	43.0	36.0	9.71	9.88	10.0

Figure 1. Distribution of the evaluated scores.

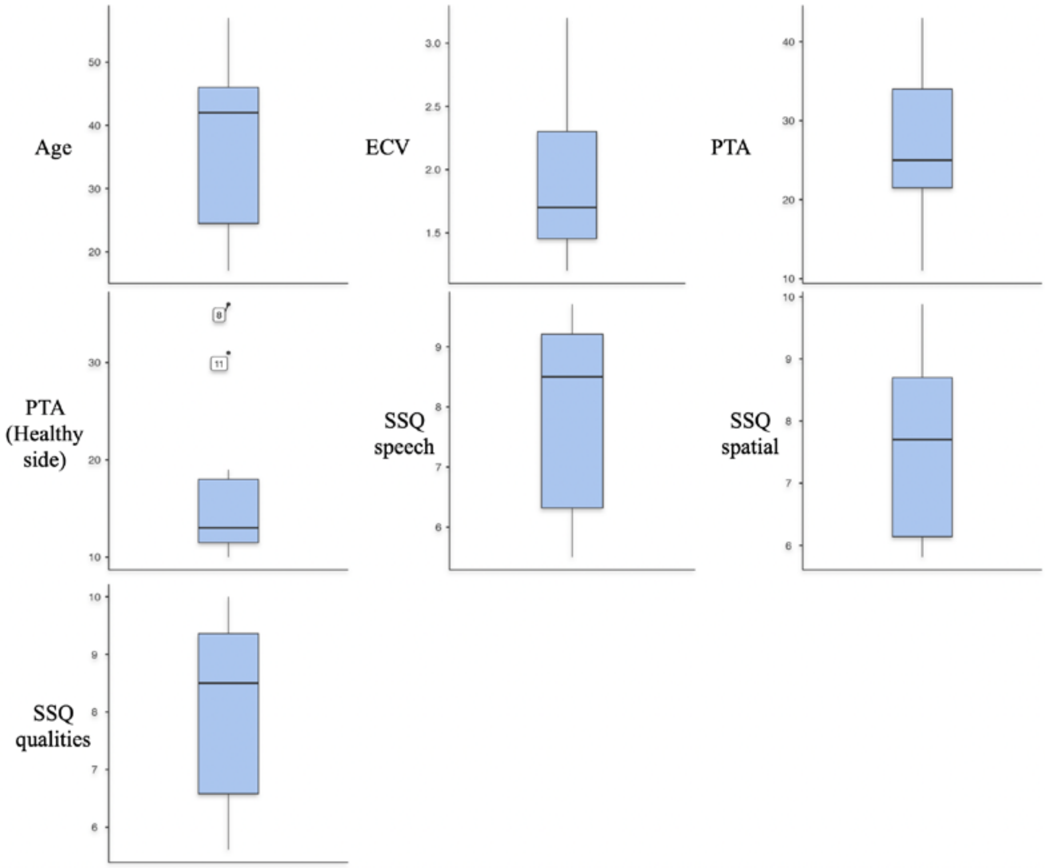

Table 2. frequency of side and MO material in our sample.

Variable		Counts	% of Total
Side	DX	6	54.5%
	SX	5	45.5%
Material	Allograft	5	45.5%
	Autologous	6	54.4%

Subsequently, we performed an analysis comparing the two groups of our sample. As could be noted, no significant differences were reported in our group of studies between patients who underwent MO with autologous bone or homologous bone.

Table 3. Comparison between the two groups of our sample based on the type of material used for the MO.

	Statistic	p
age	10.50	0.464
ecv	13.00	0.783
pta	9.50	0.360
pta_healthy_side	10.00	0.403
ssq_speech	9.00	0.329
ssq_spatial	6.00	0.126
ssq_qualities	7.00	0.177

Table 4. Descriptive analysis of the two groups of patients who received MO with two different materials.

	Group	N	Mean	Median	SD	SE
ecv	Allograft	5	2.04	2.20	0.635	0.284
	autologous	6	1.90	1.61	0.759	0.310
pta	Allograft	5	23.60	23.00	9.450	4.226
	autologous	6	29.17	29.00	11.652	4.757
pta_healthy_side	Allograft	5	13.60	13.00	3.912	1.749
	autologous	6	20.00	15.00	10.807	4.412
ssq_speech	Allograft	5	8.48	9.28	1.750	0.783
	autologous	6	7.46	7.57	1.546	0.631
ssq_spatial	Allograft	5	8.16	8.82	1.654	0.740
	autologous	6	6.98	6.91	1.213	0.495
ssq_qualities	Allograft	5	8.74	9.17	1.573	0.703
	autologous	6	7.54	7.72	1.529	0.624

Figure 2. Comparisons between outcomes in patients who underwent reconstruction with autologous graft or allograft.

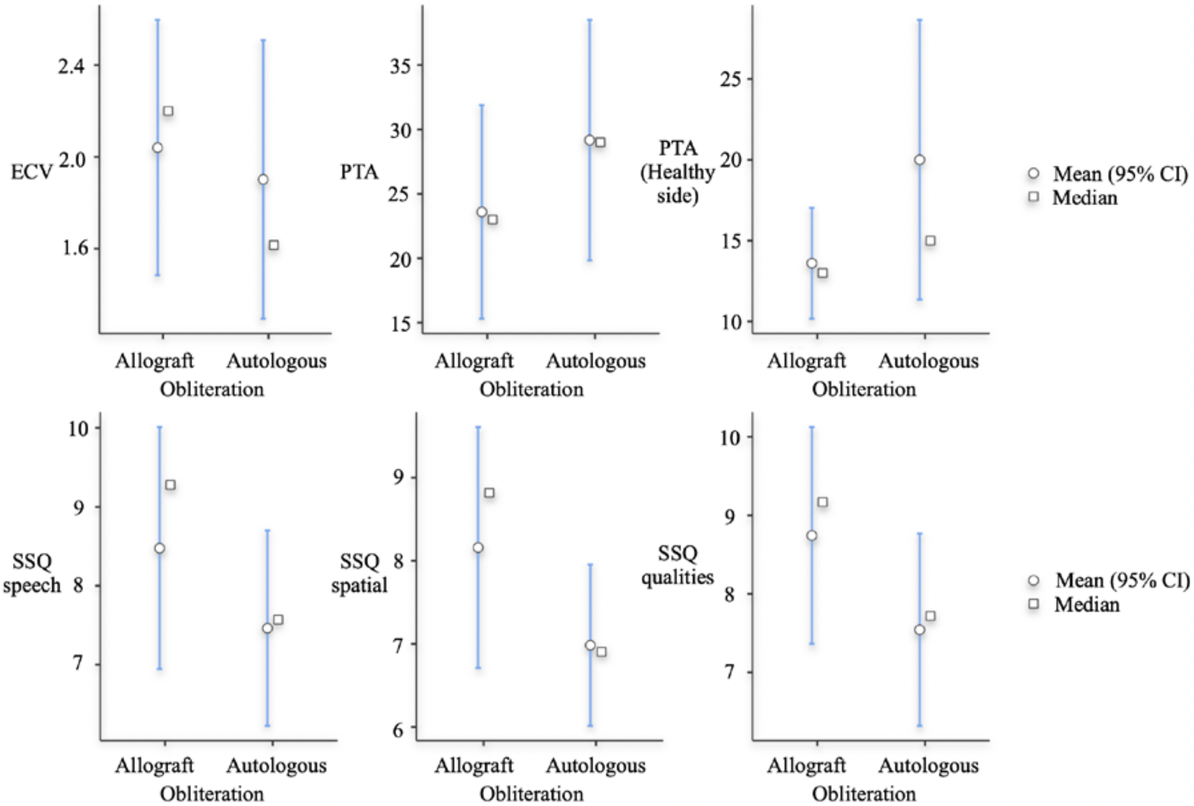

Table 5. Comparison between case series and Gatehouse and Nobel.

Variables		Gatehouse	Case series
Age		71 yy	37.5 yy
PTA (worst - operated side)		52.7 dB	26.6 dB
PTA (best - healthy side)		38.8 dB	17.1 dB
SSQ	Speech	4.38	7.92
	Spatial	5.64	7.52
	Qualities	6.34	8.09

Discussion

MO is an ancillary technique to tympanoplasty with known clinical benefits. MO enables the reconstruction of an EEC that more closely resembles clinical normality, with the possibility of reducing heat sensitivity, otorrhea and the need for recurrent medical cleanings.

MO also mitigates the alterations of the transmission of sound from the external to the inner ear, due to not-conservative surgical procedures such as CWD tympanoplasty (McElveen, 1982; Whittemore, 1998). The enlargement of the volume of the EEC can modify the resonance of the external ear (Satar, 2002) while the partial or total removal of ossicular chain to enable eradication of the disease can change the intensity and the features of sound waves to the inner ear (Browning, 1984; Weiner, 1946).

In CWD the surgeon drills the posterior and superior wall of the EEC, shaping a common mastoid cavity that includes the auditory canal and creating a new smaller middle ear. The purpose of the CWD is the clear visualisation of middle ear pathology, particularly in the retrotympanic area and the anterior epitympanum. These areas are considered some of the most critical for cholesteatoma removal and are difficult to manage in canal wall up approaches.

MO can be performed preferably in a single stage with CWD, or in a second stage. Nowadays, different procedures and materials used have been described to perform MO, with no consensus on the standardisation of procedures. The obliteration techniques include various local flaps, with or without combinations of 'free in the cavity' materials. In addition, multiple materials have been used for obliteration. They are classically divided into organic and synthetic materials. Organic materials can be autologous (e.g. bone, cartilage, muscle, fat), heterologous (bio-hydroxyapatite from animal origin) and allogenic (homologous bone from human cadaver). Synthetic materials are heterogeneous: hydroxyapatite, calcium phosphate ceramic, bioactive glass, silicone, and titanium (Hartwein, 1990; Satar, 2002).

In humans, the EEC has an average length of 26 mm, a mean diameter of 7 mm, and a volume of approximately 1 ml. The sound pressure in different portions of the EEC is not equal (Djupesland, 1973).The EEC works acoustically like a tube closed at one end, producing an increase in sound pressure at the tympanic membrane of approximately 12 dB with a peak between 3,400 Hz and 3,900 Hz as compared to the sound pressure level (SPL) at the opening of the canal. The fundamental resonance occurs at frequency corresponding to a wavelength that is four times the length of the canal. The amount of sound pressure increase depends on the acoustical impedance at the termination of the ear canal, which is provided by the tympanic membrane, middle ear structures and inner ear (Goode, 1977).

In the two groups of our sample, we measured the ECV as an important parameter to represent the restored anatomy of EEC. ECV was measured in ml. The results demonstrated post operative ECV within the normal range in every patient, so we conclude that restoring of ECV in MO is independent from the type of material used. About our choice in MO materials, we mainly used the homologous bone was mainly use when the autologous bone was not available in sufficient quantity (for cavity revisions or to obliterate very large mastoid cavities).

Goode et al (Goode, 1977) in 1977 studied four fresh temporal bones. The canal resonance was described at 5000 Hz, probably due to a short canal length of 1.7 cm. The bony canal was widened with a drill to the maximum possible diameter without entering the mastoid antrum, usually 1.2-1.4 cm. No acoustical changes were reported during the retest. When the mastoid cavity was widely opened via a transcanal approach, there was a sharp dip at the resonant peak of 24 dB and a 15 dB antiresonant dip appeared at 2500 Hz. A 12 dB resonant point appeared between 1000 and 2000 Hz. Upon closure of the aditus ad antrum with clay, there was some improvement, particularly in the 2500 Hz antiresonance.

In 1989 Evans et al (Evans, 1989) studied the resonance of temporal bones comparing patients and cadavers. They reported that a CWD mastoidectomy changes the resonant characteristics of the external auditory canal, remarking that the effect in vivo is smaller than in cadaveric temporal bones. In patients the mean peak resonant frequency of the external ear canal shifted from 2500 to 2200 Hz ($p<0.02$), in 6 temporal bones with undergone a CWD the shift was from 3900 to 1900 Hz. The authors explained this difference with a clinical consideration: the patients were generally presenting with diseased ear, more frequently sclerotic and not pneumatized. In those cases, the neocavity shaped were most frequently smaller than in healthy temporal bones.

A study by Jang et al 2002 (Jang, 2002) demonstrated the reversibility of CWD modification of EEC resonance. In fact, MO increased the resonance frequencies (2750+/-199 Hz) and reduced the peak amplitude to 20.5 +/- 1.9 dB, compared to the frequency (2350 +/-201 Hz) and the peak amplitude (22.5+/-1.7 db) of the open mastoid cavity.

A study published by Lucidi at al. (Lucidi, 2019) showed some differences between post-operative hearing results in canal wall up and CWD mastoidectomy surgery. Self-reported hearing function was found to be worse after CWD mastoidectomy in comparison with canal wall up mastoidectomy, while no difference was reported in the PTA. The explanation proposed by the authors was an altered ear canal acoustics.

In the healthy ear, the EEC acts as a filter, which reduces the low frequencies and enhances mid to high frequencies (Lucidi, 2019). In case of CWD, the acoustic properties shift toward an amplification of the soundwaves of low to mid frequencies, and a reduction in soundwaves of high frequencies.

Zwemstra et al. (Zwemstra, 2020) reported 10 the participants have had a large EEC resulted from a previous CWD. These patients have become habituated to the acoustic properties of their cavity, although they had an altered filter. Authors noted that in other fields of altered processing of sounds, habituation has been described, e.g. the neurophysiologic processes that could be extrapolated from tinnitus studies.

Van Spronsen et. al (van Spronsen, 2015) evaluated the perceptual effect of the acoustic properties before and after different procedures, including the canaloplasty and the reconstruction of the posterior canal wall in revision modified radical cavity surgery. The acoustic properties of the ear canal were characterized by measuring the real ear unaided response (REUR). REUR is measured with a probe microphone inserted into the EEC. It describes the sound pressure level at the eardrum after the presentation of broadband sound stimulus. Differences between individual REURs represent differences in acoustic properties of individual ear canals. The acoustic effect in an external ear of postoperative radical cavity, for example, can be simulated in a normal ear canal by filtering the incoming sound stimulus using the difference of the REUR of a normal ear and the REUR of a cavity ear. The filtered sound stimuli, presented to a normal ear, should result in the same distribution of sound pressure at the eardrum as in the original radical cavity. The authors simulated sound conditions of six different ear canals (two normal ears, and two pre- and postoperative conditions) and presented the broadband sound stimulus to twenty normal hearing subjects. Participants were asked which fragment sounded more natural using a seven-point comparison rating scale. The two operative conditions were surgery of exostosis of EEC and partial obliteration of the radical cavity with hydroxiapathite granules. The authors observed significant improvement in sound quality only in pre-post operative radical cavity obliteration (called in the study 'canalpalsty') and this is necessarily due to the reduction in volume of the EEC.

We enrolled a sample group in which PTA in non-operated vs operated ear corresponded to a normal -mild hearing loss (17.1 - 26.6 db). Hearing threshold was better than the control group of Gatehouse (38.8 - 52.7). PTA of 30 dB or better in CWD with MO can be considered a good audiological result (Ferlito, 2022). The PTA outcomes do not differ in the two obliteration groups.

About the hearing threshold we underline that MO can lead the support of the neotimpanum to the little-middle ear cavity more stable. Furthermore, this support is mainly achieved by the skeletal canal of the facial nerve between the second and third tracts, including its genus. Obliteration of the former epithympanum can provide greater stability to this system, especially in myringoplasties performed with cartilage.

Established a better PTA in our sample, we hypothesized that, thanks to MO and restoration of a normal EEC, also subjective hearing autoanalysis in SSQ should be better in our patients as compared to the control group. This inference has been proven in the three domains of the SSQ questionnaire and this was valid for the two types of obliteration.

The assumption of the beneficial MO would have been denied if the answers to the SSQ questionnaire of the patients in our sample had been on average worse than the control group.

SSQ questionnaire was chosen because it represents some common listening situations but focuses mainly on competitive listening, as well as localization-in-noise situations. SSQ answers emphasise the competence of binaural hearing. Results of our sample demonstrate the high subjective quality of hearing after a normally disabling surgery such as CWD, in a descriptive but more meaningful way than the PTA alone. That is the real benefit of MO.

The limit of our study is the small number of our sample. It will also be necessary to create our own control group of patients with altered EEC and consequently altered ECV (for example CWD without MO).

Conclusions

MO after CWD technique makes possible a reconstruction of EEC respectful of a normal ECV. Results in volume are similar in the two MO materials used in our institution. In our sample the SSQ questionnaire results for good quality of hearing, despite our patients undergone surgery. The subjective results are the natural consequence of a normal physiological repristination of the anatomy as well as being the consequence of a good PTA.

We think that MO with autologous material (or homologous when autologous is not available) is a safe option in recreating a natural condition of hearing after CWD tympanoplasty.

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