Open Mastoid Cavity Obliteration With a High-Porosity Hydroxyapatite Ceramic Leads to High Rate of Revision Surgery and Insufficient Cavity Obliteration

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Open Mastoid Cavity Obliteration With a High-Porosity Hydroxyapatite Ceramic Leads to High Rate of Revision Surgery and Insufficient Cavity Obliteration

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Objective: To assess long-term results and present experience with a high-porosity hydroxyapatite ceramic for obliterating large open mastoid cavities.
Study-Design: Cross-sectional cohort study.
Setting: Tertiary academic referral center.
Patients: All patients who underwent tympanomastoid surgery for chronic middle ear disease or revision surgery with reduction of an open mastoid cavity using a highly porous hydroxyapatite matrix material (HMM) between May 2005 and June 2013 were assessed for eligibility. Twenty three patients (56.9 ± 18.3 yr) were included.
Intervention: Primary middle ear surgery or revision surgery using a HMM.
Main Outcome Measures: Pure-tone average, computed tomography (CT), and magnetic resonance imaging (MRI) to investigate osseoinduction, osseointegration and presence of cholesteatoma, current quality of life assessed by Zurich Chronic Middle Ear Inventory and change in quality of life post-intervention assessed by the Glasgow Benefit Inventory.
Results: Patients were reexamined after a mean follow-up period of 88.3 months (SD 21.4 mo) after obliteration of the open mastoid cavity with HMM. Compared with visit 1, patients showed a significantly reduced ABG at visit 2 (29.22 dB ± 2.71 dB versus 12.77 dB ± 3.46 dB).
CT scan was carried out in 21 patients (91%) patients and 17 patients (74%) underwent MRI.
Revision surgery was required in a total of 17 cases (74%). In four patients recurrent cholesteatoma was found at follow up.
Conclusions: Poor cavity obliteration, a high rate of revision surgery and difficult differentiation between recurrent cholesteatoma and granulation tissue in CT scan was observed.
Key Words: Allogeneic bone pate—Cholesteatoma—Chronic middle ear disease—High-porosity hydroxyapatite ceramic—Open mastoid cavity obliteration.

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Tympanoplasty is performed in patients with chronic middle ear disease, e.g., cholesteatoma or chronic otitis media, to restore the tympanic membrane and the sound conduction system, but also in patients with previous ear-surgery, where the ossicles were involved in the disease, to achieve better hearing performance. In case of an extension of the cholesteatoma into the mastoid, canal wall up versus canal wall down techniques are differentiated. Reasons for the creation of an open mastoid cavity can be the extend of cholesteatoma or the inflammation process. Depending on the extend of the open mastoid cavity and the meatal size, the self-cleaning process can be disturbed, leading to recurrent ear-infections, secretion, vertigo, hearing impairment, and frequent consultation of an ENT-specialist (1).

In these cases, the treatment of choice consists of surgical obliteration of the open mastoid cavity in combination with a meatoplasty. Multiple methods and materials for obliteration have been developed (2). Usually, the use of autologous material is preferred due to its good biocompatibility. Cartilage, either from the concha, tragus or nasal septum, muscle-flaps, bone-pâté, or fascia can be used. Negative aspects can be the natural shrinkage and the limited availability of autologous material after repeated revision surgery (3). For this reason, diverse xenografts and alloplastic materials have been

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designed and tested (4,5). However, the mechanism of the biomaterial-based regeneration process is still mostly unexplored.

Alloplastic material is easily available but causes additional material expenses to the healthcare system. In addition, wound infections due to rejection reactions, granulations, and inflammation reactions have been described (2,6). On the other hand, alloplastic materials could save surgical time for harvest and reduce comorbidities at the donor side.

Highly porous hydroxyapatite matrix material (HMM) is frequently used in maxillofacial surgery and showed stable long-term results in a 3-year-follow-up investigation of implant stability (7). Histological and histomorphometric changes in clinical application of synthetic (HMM) and xenogeneic bone substitute (XBM) materials in head and neck cancer patients showed significantly greater vascularization and a higher number of multinucleated giant cells in the HMM group compared with the XBM group. HMM was degraded by the multinucleated giant cells and replaced mainly by connective tissue, whereas XBM remained in the implantation bed, serving as a spacer (8). Animal experiments demonstrated that the vascularization and biodegradation in the HMM implantation bed reached its peak after 10 days with relatively few multinucleated giant cells and macrophages. Mononuclear cells, such as macrophages, were also found on the bone substitute material (9,10). Histological investigations of the synthetic bone substitute material HMM used in humans for paranasal sinus augmentation showed integration of the granules into the host tissue 6 months after augmentation as well as newly formed bone in all parts of the augmented region (11,12).

First experience with an alloplastic material consisting of hydroxyl-apatite matrix (HMM) show a good biocompatibility in animal experiments after implantation into adipose neck tissue of rats (13) and into guinea pig bullae (14,15). In a number of consecutive animal and clinical trials, HMM has been investigated with regard to the basis of its physiochemical structure and integration in animal implantation models as well as in human tissue (7–12).

Short term clinical results (29 mo) of 20 patients after mastoid cavity obliteration with HMM showed an uneventful healing and a reduction of vertigo, otorrhea, and frequency of medical consultation (16). Literature review regarding the revision rate at long-term follow up after open mastoid cavity reduction identifies many studies on follow up of patients after a period of 2 years or later using autologous material but only few data is available on long-term results with allogeneic material (Table 1). Revision rates between 0 and 38% are reported. HMM resulted in high complication rates with a rejection rate of 20% in a case population of n = 18 (17).

We hypothesize that the clinical follow-up for cholesteatoma after obliteration of an open mastoid cavity using HMM is disturbed by the consistence and the surrounding cellular reaction induced by HMM impeding the differentiation between allograft and recurrent cholesteatoma in radiologic and clinical follow-up examinations. The aim of this study was to analyze the long-term results of patients receiving HMM after tympanomastoid surgery with regard to the identification of recurrent cholesteatoma, changes in tomography imaging, number and feasibility of revision surgery, quality of life, and audiological outcome.

METHODS

Ethical Consideration

The study protocol was approved by the local Ethics Committee in accordance with the Helsinki declaration (registration-number: A2017–0101). Informed consent was obtained from all the participants.

Study Design and Patient Selection

In this cross-sectional cohort study, patients receiving open mastoid cavity obliteration using HMM between May 2005 and June 2013 were assessed for inclusion (Fig. 1). Patients were recruited from a tertiary hospital, a university medical center. Visit 1 was defined as preoperative investigation before the obliteration of the mastoid cavity with HMM, visit 2 as the latest follow-up available.

Patients included in the study underwent MRI and CT imaging, pure-tone audiometry and completed two questionnaires (see below) as part of the current study at visit 2. Further, a retrospective chart review was carried out, including assessing previous ear surgery (primary versus revision), the condition of the tympanic membrane (intact versus defect), and the presence of cholesteatoma at the time of surgery.

Bone Grafting Substitute

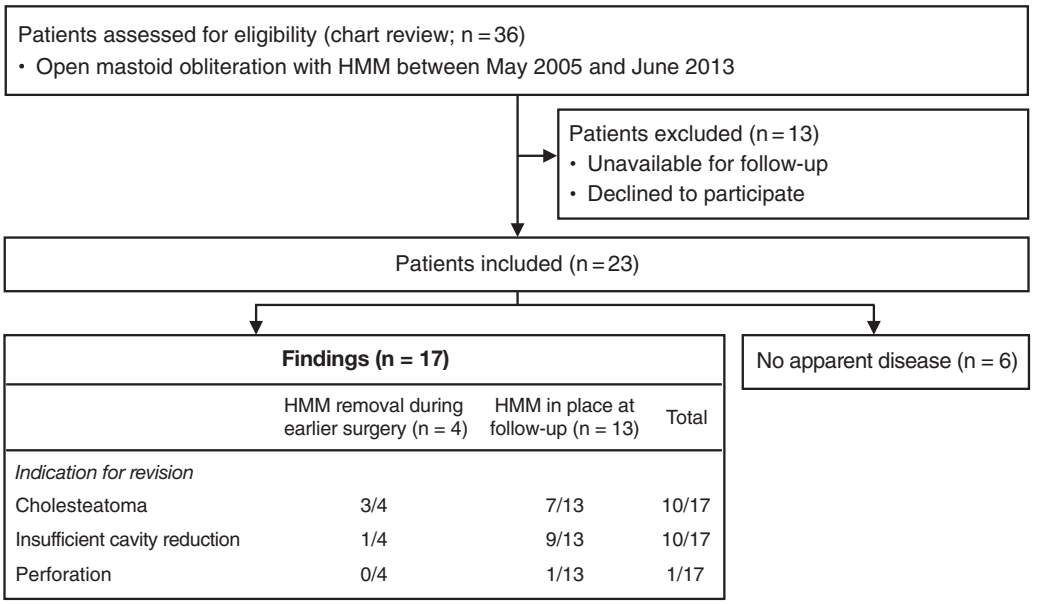
NanoBone (Artoss GmbH, Rostock, Germany) is a fully synthetic bone substitute granule, it consists of hydroxyapatite crystallites with an average size of 60 nm in each crystallographic direction that are embedded in a matrix of silica gel (18). It is produced by a sol–gel technique at temperatures below 700 °C, avoiding sintering of the nanocrystalline hydroxyapatite (18). The biomaterial is characterized by open bonds that are responsible for an internal surface of up to 84 m^2/g in size. The pore size distribution within the silica gel ranges from 10 to 20 nm in diameter. Macroscopically, the granules have a length of around 2 mm and diameter of 0.6 mm.

Audiometric Assessment

All audiometric measurements were performed with calibrated instruments in a sound-proof room (DIN EN ISO 8253). Measurements included standard pure-tone audiometry (air conduction: 0.25–8 kHz; bone conduction: 0.5–6 kHz), performed with a clinical audiometer (AT1000, Auritec, Hamburg, Germany) by an experienced audiologist in 5 dB steps. Operators were blinded with respect to the type of intervention. Airbone gaps (ABG) were calculated as the difference between the pure-tone averages of the air-conduction thresholds measured at 0.5, 1, 2, and 3 kHz ($PTA_{0.5-3\,kHz}$) and the respective average bone conduction thresholds. According to recommendations in hearing reporting standard (19) and to the Committee on Hearing Equilibrium guidelines (20), the $ABG_{0.5-3\,kHz}$ was chosen for evaluating the results of treating conductive hearing loss. Therefore, only the $ABG_{0.5-3\,kHz}$ was further analyzed and is referred to as ABG. Preoperative audiometric results (visit 1) and at the latest follow-up (visit 2) were collected.

TABLE 1. *Study review of long-term follow-up investigations of different open mastoid cavity obliteration materials*

Title	Author	Journal	Year	Number of Ears Observed (n)	Time Period	Follow-up Period (yr)	Obliteration Material	Revision Rate (%)
Long-term results following mastoid obliteration in canal wall down tympanomastoidectomy	D Beutner, R Stumpf, T Zahnert, KB Hüttenbrink	Laryngo-Rhino-Otology	2007	39	1993–2001	6	Cartilage, bone pate	18 3: recurrent cholesteatoma 10: prosthesis dislocation 5: ventilation tubes
Obliteration of radical cavities with autogenous cortical bone; long-term results	AM Abdel-Rahman, M Pietola, TJ Kinnari, H Ramsay, J Jero, AA Aarnisalo	BMC ear, nose and throat disorders	2008	70	1986–1991	18	Bone chips, bone paté, meatally-based muskelperiostal flap	30 9: mastoid cavity 13: meatoplasty 3: myringoplasty 10: tympanoplasty
Long-term results of canal wall reconstruction tympanomastoidectomy	PC Walker, SE Mowry, MR Hansen, BJ Gantz	Otology & Neurotology	2014	285	1997–2011	4.3	Bone pate	8.5
Obliteration of mastoid cavities. 30 years of experience with recommendations for surgical strategy	G Schimanski, E Schimanski	HNO	2015	843	1983–2014	2.75	a) Bone pate 4 b) Palva-flap 17 c) Bone/cartilage 61 d) Bioactive glass 16 e) Hydroxyapatite 2	a) Bone pate: 9 b) Palva-flap: 20 c) Bone/cartilage: 7 d) Bioactive glass: 5 e) Hydroxyapatite: 11
Clinical study surgical results of retrograde mastoidectomy with primary reconstruction of the ear canal and mastoid cavity	CY Kuo, BR Huang, HC Chen, CP Shih, WK Chang, YL Tsai, YY Lin, WC Tsai, CH Wang	BioMed Research International	2015	102	2004–2013	2	Cartilage-chips-, paté	0
Long-term results of troublesome CWD cavity reconstruction by mastoid and epitympanic bony obliteration (CWR-BOT) in adults	JP Vercruysse, JJS van Dinther, B De Foer, J Casselman, T Somers, A Zarowski, C Cremers, E Offeciers	Otology & Neurotology	2016	50	1998–2009	8.5	Bone pate and bone chips,	4
Canal reconstruction and mastoid obliteration using floating cartilages and musculoperiosteal flaps	HJ Lee, JR Chao, YK Yeon, V Kumar, CH Park, HJ Kim, JH Lee	The Laryngoscope	2016	33	2008–2015	1.7	Cartilage, mucoperiostal flap	0



	HMM removal during earlier surgery (n = 4)	HMM in place at follow-up (n = 13)	Total
Indication for revision			
Cholesteatoma	3/4	7/13	10/17
Insufficient cavity reduction	1/4	9/13	10/17
Perforation	0/4	1/13	1/17

FIG. 1. Study flow chart; CT not available in n = 2 patients where the HMM had already been removed during previous surgery; MRI not available in n = 6 due to contraindications for MRI-investigation or due to bad physical conditions. CT indicates computed tomography; HMM, hydroxyapatite matrix material; MRI, magnetic resonance imaging.

Radiological Assessment

All CT examinations were performed on a 64-row CT scanner (Aquillion 64, Canon Medical, Tustin, CA). Representative CT imaging protocol was the following: volumetric acquisition from above the ear below the level of the skull base; 120 kV, 150 mA. All CT dataset were reconstructed in axial and coronal planes in bone window/level settings with a standard field-of-view (FoV; 22 cm) with a slice thickness of 1 mm and a slice gap of 0.5 mm.

All MR examinations were performed at 1.5T (Avanto Fit, Siemens Medical System, Erlangen, Germany) using a 20 channel head coil for signal detection. Following the localizer, an axial T1-weighted (T1w) Spin Echo (SE) sequence was acquired. Imaging parameters were time of repetition (TR)/time of echo (TE) 450/8.5 ms, FoV 180 mm, matrix size 192×256 with an in-plane resolution 0.7×0.7 mm and a slice thickness of 3 mm. Next, a coronal T2-weighted (T2w) Turbo Spin Echo (TSE) sequence was acquired (imaging parameters: TR/TE 3500/79 ms, FoV 170 mm, matrix 192×256, in-plane resolution 0.3×0.3 mm, slice thickness 3 mm) followed by a T2w HASTE (Half Fourier Single shot TSE) diffusion weighted sequence with one *b*-value $b = 1000\,\text{mm/s}^2$ (imaging parameters: TR/TE 2000/103 ms, FoV 200 mm, matrix 144×192, in-plane resolution 0.5×0.5 mm, slice thickness 3 mm). After contrast administration of 0.1 mmol gadobutrol (Gadovist, Bayer, Germany) per kg bodyweight a T1w VIBE (Volume Interpolated Breathold Examination) with fat suppression (imaging parameters: TR/TE 9/2.38 ms, FoV 200 mm, matrix 192×256, in-plane resolution 0.8×0.8 mm, slice thickness 0.8 mm) with multiplanar reconstructions in coronal plane was acquired.

Questionnaires

The Zurich Chronic Middle Ear Inventory (ZCMEI-21) was used to assess current quality of life (21). The ZCMEI-21 consists of four subscales concerning ear signs and symptoms, hearing function, psychosocial impact, and the use of medical resources. Answers are presented using a five-point Likert-scale. High scores correlate with a poorer quality of life (21). The ZCMEI-21 was designed as a disease-specific instrument to assess health-related quality of life in patients suffering from chronic middle ear disease and may also be used after surgical interventions. To assess change in quality of life after surgery, the Glasgow Benefit Inventory (GBI) was used (22). The GBI is a well-studied and validated outcome instrument that was proved to be maximally sensitive to otosurgical interventions. Responses to the GBI are based on a five-point Likert-scale. Scores range on a benefit-scale from −100 (maximal negative effect) to 0 (no effect) to +100 (maximal positive effect).

Statistical Analysis

All statistical tests were selected before data collection. Statistical analyses were performed using Microsoft Excel and Prism (version 7, GraphPad Software, La Jolla, CA). The significance level was set to $p < 0.05$. The assumption of normality in ABG distributions was tested using visual inspection as well as the D'Agostino-Pearson normality test. If not otherwise specified, data are presented as mean with standard deviation (SD) or absolute numbers with percentages.

RESULTS

A total of 36 patients receiving tympanomastoid surgery using HMM between 2005 and 2013 were assessed for inclusion, of which 23 patients were available for follow-up investigation (16 women and 7 men; mean age 56.9 yr, 12 right and 11 left ears) and were analyzed. Cholesteatoma was the underlying chronic middle ear disease in every case. The open mastoid cavity was either preexisting or it was created during surgery. Median interval between the creation of the open mastoid cavity and the obliteration with HMM was 22.6 ± 17.1 years. In only one case, the mastoid cavity was created during

surgery and obliterated during the same procedure. In the remaining 22 cases, the cavity was preexisting from previous tympanomastoid surgery. The mean time period between the obliteration of the open mastoid cavity and the follow-up visit was 7.4 ± 1.8 years. A total of eight patients (35%) had revision surgery in the time between the HMM obliteration and the last follow-up investigation. In four cases (17%), the HMM obliteration material had already been removed during previous surgeries, leaving 19 patients (83%) with remaining HMM in the mastoid cavity. The reasons for removal of the bone substitute were recurrent cholesteatoma in three cases and an insufficient cavity reduction in one case.

Compared with visit 1, i.e., the preoperative visit, patients showed a significantly reduced ABG at visit 2, i.e., the latest follow-up available (mean difference -16.45 ± 4.39 dB, $p = 0.0005$; Fig. 2A). No significant difference was found between the bone conduction thresholds at visit 1 and visit 2 (mean difference 8.2 dB, $p = 0.08$; Fig. 1B). The presence of cholesteatoma and the status of the tympanic membrane (defect versus intact) by the time of surgery did not have a significant influence on the audiological outcome defined as ABG shift.

At visit 2, 11 patients (48%) had a positive test of Valsalva, seven patients (30%) reported to suffer from otorrhea, three patients (13%) complained about recurrent otalgia, seven patients (30%) about tinnitus and seven patients (30%) about caloric induced vertigo. In only one case (4%), the tympanic membrane reconstruction was perforated, in the remaining 22 cases (96%), it was intact. In 17 cases (74%), the mastoid cavity was dry, in two cases (9%), there were signs of an infection, and in four cases (17%), the extent of the mastoid cavity was not completely visible. Revision surgery was indicated in nine cases (39%). In four cases (17%) revision surgery was indicated due to recurrent cholesteatoma, in the other cases to reduce the cavity size, due to chronic infections and for hearing-improvement. In one case a perforation of the tympanic membrane was found additionally. In all of those cases, the obliteration material was still in place. The cavity was sufficiently obliterated and observable in only nine cases (39%) at follow-up. Together with the revision surgeries that had been performed in the time between the initial surgery with HMM and the follow-up, a total number of 17 patients (74%) had to be revised after the open mastoid cavity obliteration with HMM, leaving only a number of six patients (26%) without apparent disease (Fig. 1).

CT scans were conducted in 21 patients (91%) patients and 17 patients (74%) underwent MRI including non-epi diffusion weighted imaging (HASTE-DWI). In one case neither CT nor MRI was possible due to the poor physical condition. In six cases (26%), MRI was not possible due to either non-MRI safe implants (e.g., pacemakers) or due to allergies to contrast enhancers. In four cases, the diagnosis of recurrent cholesteatoma was made clinically, i.e., by otoscopic inspection. In these cases, HASTE sequence showed signs for cholesteatoma in only one case (25%). In seven cases (30%), CT imaging showed soft tissue in the mastoid.

Figure 3 shows the CT- and MRI-scans of an exemplary patient, where the HMM is well integrated. Craniodorsally, a soft tissue cover can be seen as marked by the arrow (Fig. 3B). The MRI shows no signs of cholesteatoma (Fig. 3C, D). The same patient underwent revision surgery because of retraction pockets in the tympanic cavity (Fig. 3E–G). The HMM was partially removed and replaced using autologous material.

Figure 4 illustrates the time-course of a patient, who had CT-scan before and twice after revision surgery due to clinically suspected cholesteatoma with otorrhea. Figure 4A shows the CT-scan previous 1st revision surgery where an irregular surface of the obliteration material indicates recurrent cholestetoma. Revision surgery was performed due to recurrent cholesteatoma. Three years after revision surgery (Fig. 4B) and 7 years after surgery (Fig. 4C), the appearance of the material

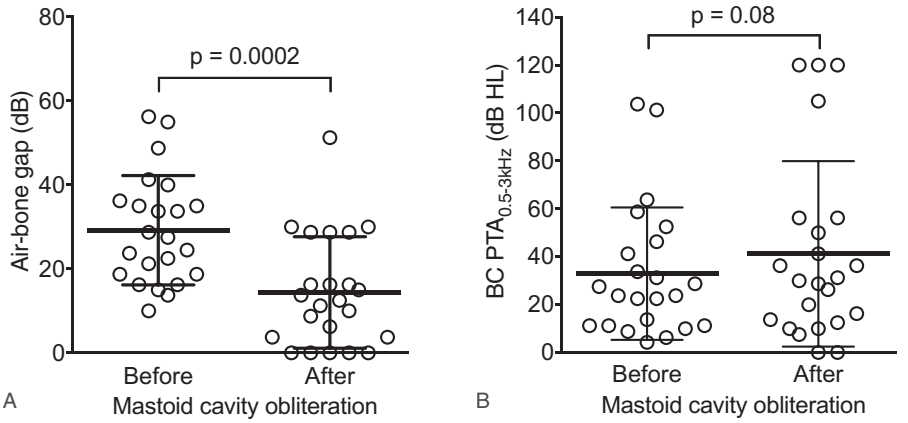


FIG. 2. Audiometric results *A*, air-bone gap ($ABG_{0.5-3\,kHz}$) before and after mastoid cavity obliteration. *B*, Bone conduction threshold before and after mastoid cavity obliteration. Bold line indicates mean, error bars indicate standard deviation.

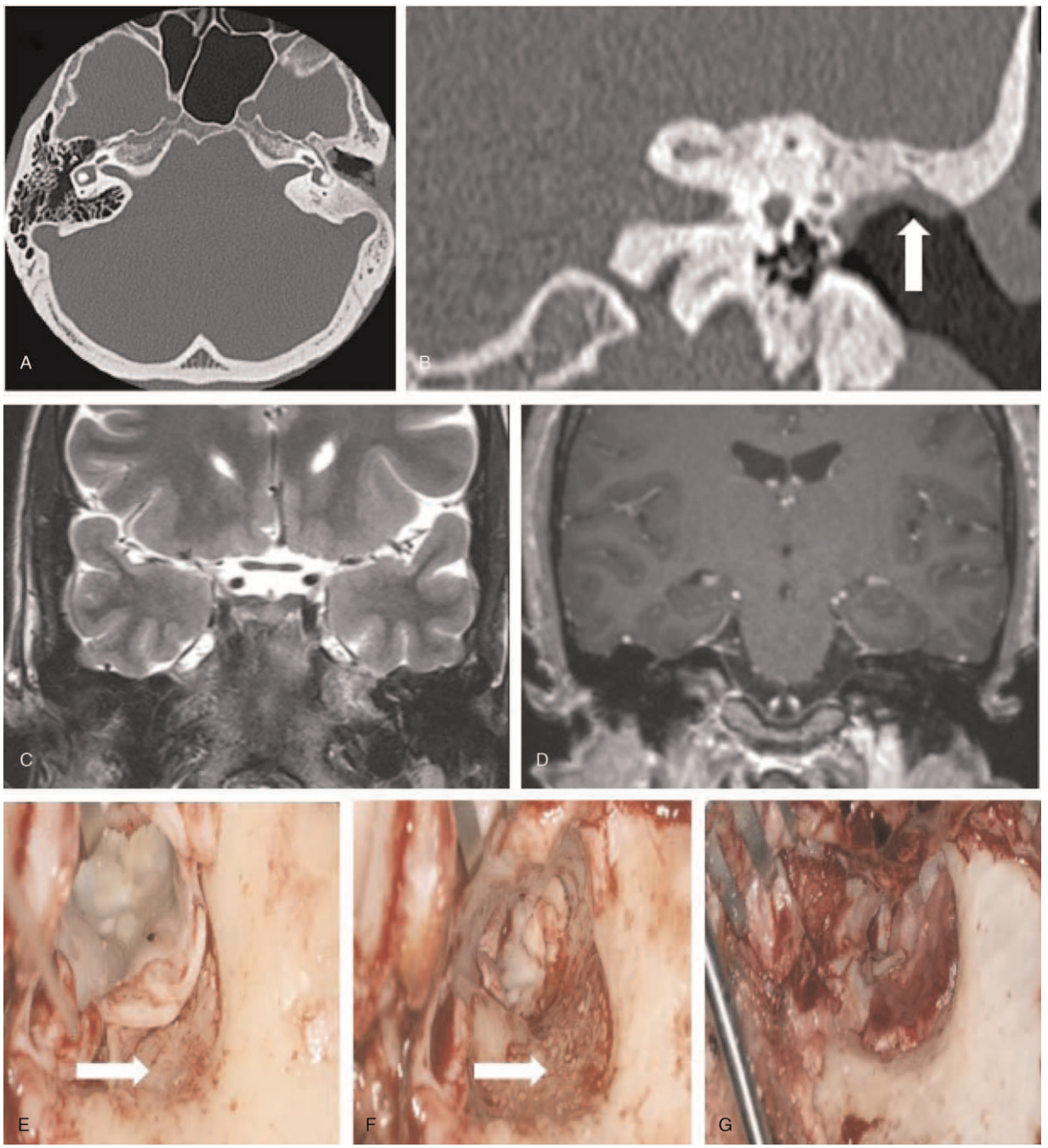


FIG. 3. CT- and MRI-scans as well as intraoperative pictures of revision surgery of one of the patients, with the HMM still in place. *A*, CT axial view, *B*, CT coronar view, *C*, coronar MRI in T2-sequence, *D*, coronar MRI in T1-sequence. A/B Craniodorsally, a soft tissue formation can be seen as marked by the arrow (B, C, and D). The MRI shows no hints for cholesteatoma. Intraoperatively, the HMM marked by the arrow in *E* and *F* was removed and the open mastoid cavity was reduced using autologous material (*G*). CT indicates computed tomography; HMM, hydroxyapatite matrix material; MRI, magnetic resonance imaging.

remains stable and a continuous integration and a discrete shrinkage can be seen. Figure 4D shows the histology of the resection material of the same patient. The material shows a partially integrated HMM with adjacent connective tissue.

At visit 2, mean ZCMEI-21 score was 26.6 ± 13.2, which corresponds to a mildly to moderately impaired quality of life (21,23). Mean GBI score was 0.3 ± 15.0 indicating neither a positive nor a negative subjective effect of the surgery (Fig. 5).

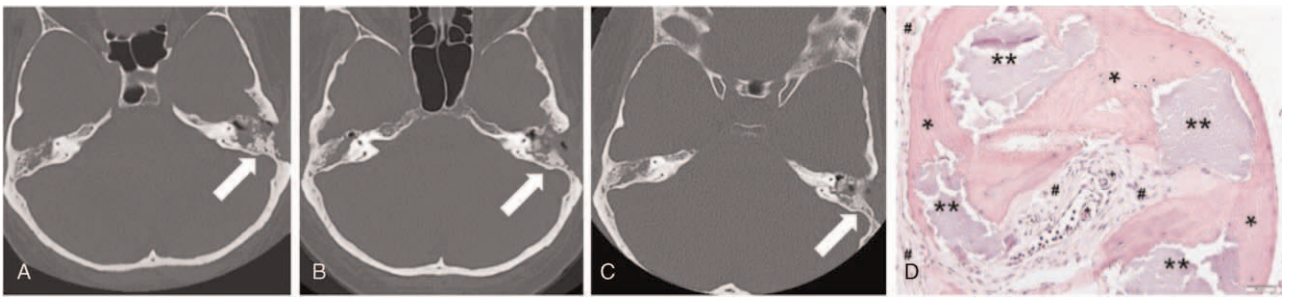


FIG. 4. Time-course of HMM in the CT-scan and histological appearance: *A* shows the preoperative CT-scan before revision surgery showing an irregular surface of the obliteration material. *B*, Postoperative control in 2014 and *C*, in 2018. The appearance of the material remains stable and a continuous integration and a discrete shrinkage can be seen. *D*, Histology of the HMM in hematoxylin-eosin stain, showing a partially integrated HMM with adjacent connective tissue. (* bone, ** HMM, # connective tissue, + capillary). CT indicates computed tomography; HMM, hydroxyapatite matrix material.

DISCUSSION

This is the first long-term investigation of patients where HMM was used for obliteration of open mastoid cavities investigating a time period of this extent. Noticeable was the high number of persistent discharging and poorly observable mastoid cavities.

Open mastoid cavity reduction is performed to improve the patient's quality of life by reducing the amount of caloric vertigo, otorrhea as well as to reduce the frequency of consultation of an ENT-specialist (6). This aim was achieved in only 39% of the patients in this study. A study investigating the GBI-score after open mastoid cavity obliteration with autologous bone showed a significant improvement in the QoL (24). In this cohort, the total GBI-score, describing the subjective benefit from the mastoid obliteration showed a mean of 0.3 ± 15.0, indicating no subjective benefit at all according to the clinical observations. The scores correlated well with the ZCMEI-21-scores, a newly evaluated questionnaire investigating the patient's quality of life concerning chronic middle-ear diseases.

For surgery, autologous and alloplastic materials are used. HMM is an evolved hydroxyapatite material that has been used successfully in maxillofacial surgery (25). It is rarely used in ENT-surgery for open mastoid cavity obliteration. The hydroxyapatite bone substitute is said to have an osseogenetic effect that was proven in an animal experiment (26). New bone formation could be observed in clinical trials after 3 months already, making the material attractive with respect to wound healing and low rejection reactions (12). The supporting arguments for allogeneic material are its lack of shrinkage and the easy access (14–16).

Studies on cellular changes induced by the material showed a significant degradation of the material due to macrophage, giant-cell, and lymphocyte absorption leading to material shrinkage and like that to an insufficient material substitution (9,27). This observation is comprehensive and substantiated, regarding data of the present study. The large majority of patients was found to have a persistent open mastoid cavity at the follow-up visit and in the CT scan, leading to the assumption, that the obliteration material was either used hesitantly or that osseointegration leads to shrinkage.

Ghanaati et al. (10) showed in his histological studies, that there is no osseoinduction by the material, contrary to the suspected opinions mentioned above. Additionally, it showed, that part of the material was resorbed by macrophages and giant cells, leading to the formation of fibrous tissue rather than bone, thus making the postoperative discrimination between fibrous tissue and recurrent cholesteatoma difficult. This observation was also made in 30% of the CT-scans in this study.

Since the covered mastoid cavity is not as easily accessible for revision surgery, the lack of appropriate follow-up opportunities differentiating between fibrous tissue and cholesteatoma is regarded as disadvantageous.

CT examinations cause radiation exposure to the patient and should therefore be avoided as follow-up examinations on a regular basis. MRI, which is often recommended to be highly sensitive in cholesteatoma detection (28,29) and allows the differentiation between scar tissue formation and recurrent cholesteatoma, cannot be performed in patients with non-MRI-safe implants as seen in six patients in our study or in case of other contraindications. Furthermore, MRI is of limited value in the evaluation of the bony structures of the skull base and the possible osseous integration of the obliteration material. Small cholesteatomas cannot always be sufficiently identified (29). Finally, from the socio-economic point of view, MRI is cost-intensive for routine follow-up imaging if there are no clinical signs of recurrent cholesteatoma.

Comparing our results to other studies, large analyses of open mastoid cavity obliteration with different obliteration-materials showed rejection responses of hydroxyapatite (HA) and confirmed a higher revision rate compared with bone or cartilage (17). In this cohort, the rate of revision surgery was exceptionally high (74%) compared with other long-term follow-up investigations as seen in Table 1. Thus leading to the assumption, that the longer the follow-up period is chosen, the more often complications occur.

As a consequence, it can be assumed, that HMM itself is a stable and biocompatible material for bone

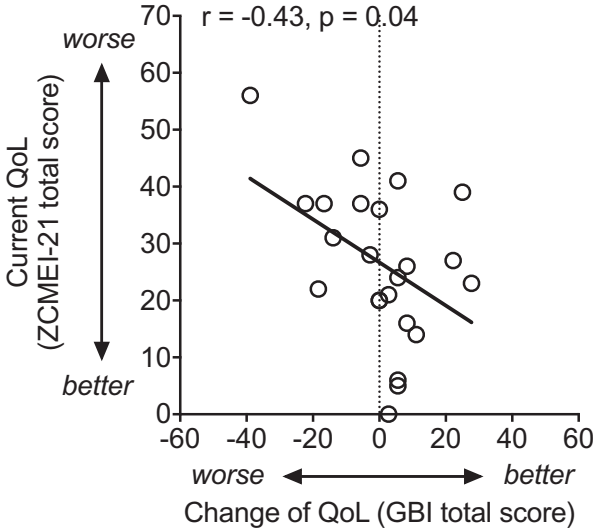


FIG. 5. Current quality of life and change in quality of life after mastoid obliteration with HMM. Current quality of life was assessed using the Zurich Chronic Middle Ear Inventory (ZCMEI-21) and change in quality of life after mastoid obliteration was assessed using the Glasgow Benefit Inventory (GBI). The dashed line indicates a total score of 0 in the GBI representing no change in quality of life after mastoid obliteration; the solid line indicates linear regression line; *r*, Pearson's correlation coefficient.

replacement outside the mastoid but does not positively influence the course of the chronic middle ear disease. It can be useful in cases where multiple revision surgeries are necessary with lacking opportunities for autologous material, but we assume, that the use is challenging concerning the correct dosage of the material. Not leaving the cavity too narrow has to be weighed against the correct amount needed for sufficient cavity reduction and has also not to be underestimated.

CONCLUSION

In this study, a poor cavity obliteration and a high rate of revision surgery (74%) was observed at late follow-up (visit 2) in this study group. The material was proved to be a good bone substitute material outside the mastoid. In the case of cholesteatoma-surgery, it has to be regarded critically since cholesteatoma is a chronic disease with several microbiological aspects involved. The cholesteatoma and the accompanying inflammation of the perimatrix can lead to an infiltration of the bone around the HMM. The keratinizing squamous epithelium of the cholesteatoma does not lead to resorption of the material but forms biofilms on the HMM that can be an additional reason for the high rate of persistent superinfections of the open mastoid cavity and the consecutive high revision rate. A superiority to autologous material cannot be assumed from these results.

The opportunities of tomography imaging for aftercare-options are limited. In CT scans, it was hard to differentiate between recurrent cholesteatoma and granulation tissue. This observation confirms other studies that showed, that further characterization between soft-tissue and cholesteatoma needs additional MRI-investigation (30). MRI is not able to detect small cholesteatomas and is not accessible for every patient.

As a consequence, we conclude, that HMM is not recommendable for the use in the mastoid, particular for mastoid obliteration. These results should carefully be taken into account by any surgeon considering an artificial agent to obliterate mastoid cavities.

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