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Review

Mastoid Obliteration with Synthetic Materials: A Review of the Literature

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Canal wall down mastoidectomy is a surgical technique used for the eradication of middle ear disease. The remaining large mastoid bowl is associated with a number of issues; one of the main techniques that have been developed in order to avoid such problems is the obliteration of the mastoid cavity. The materials used for this reason are either biological or synthetic. The purpose of this survey is to review the published literature related to the therapeutic value of mastoid obliteration with synthetic materials. We searched Web of Science, PubMed, and MEDLINE from 2008 to 2018 using the criteria mastoid obliteration, canal wall down mastoidectomy, chronic otitis media, and cholesteatoma. The search focused on papers concerning the mastoid obliteration with synthetic material, as we focused on looking for outcomes and reported complications. Out of a total of 244 citations, 15 articles were identified, where patients underwent mastoid obliteration with synthetic materials. Most authors used bioactive glass as a filler material. Mastoid obliteration resulted in a decrease in the complications associated with the open mastoid cavity. On the basis of the available limited literature, it seems that mastoid obliteration with synthetic materials is a valuable and safe surgical technique for patients who undergo canal wall down mastoidectomy. The bioactive glass appears to be the most reliable synthetic material.

KEYWORDS: Mastoid obliteration, cholesteatoma, canal wall down mastoidectomy, synthetic materials, bioactive glass, hydroxyapatite

INTRODUCTION

Two are the main goals of the treatment for cholesteatoma are the eradication of disease and prevention of its recurrence. The canal wall down (CWD) technique has traditionally been associated with quite a low recurrence rate [1]. However, this surgical procedure has many disadvantages associated with the persistent mastoid bowl (open tympanomastoid cavity); a large cavity may cause chronic ear discharge not responding to pharmaceutical agents, vertigo on exposure to water, and exhibit a tendency of debris accumulation in the mastoid cavity that requires frequent cleaning [1]. Moreover, patients with compromised hearing loss are unable to wear traditional hearing aids.

One of the main surgical interventions used for the treatment of an open mastoid cavity and all the related problems is mastoid obliteration. Two are the types of materials used for mastoid obliteration: biological (autologous grafts, allografts, and xenografts) and synthetic [2]. Biological materials are the best option for mastoid obliteration and reconstruction of the posterior ear canal, but they have disadvantages such as resorption, atrophy, difficulty in fashioning, and donor site morbidity. It is often challenging to find enough material because of the number of previous operations [3-4]. To address these problems, artificial materials such as bioactive glass (BAG), hydroxyapatite (HA), titanium, and silicone have been introduced [5-7]. Benefits of synthetic materials are that they are easy to use, uncontaminated, and theoretically endlessly available [8]. Moreover, they save considerable time in the operative technique, as minimal or no meatoplasty is required [9].

The objective of this review is to evaluate the effectiveness of mastoid obliteration using synthetic materials in patients who underwent CWD mastoidectomy and to discuss the literature regarding the types of available materials for this reason.

MATERIALS AND METHODS

We searched Web of Science, PubMed, and MEDLINE databases from 2008 to 2018 for original articles and case series concerning the mastoid obliteration with synthetic materials in CWD mastoidectomy. Only articles in English were reviewed.

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The following terms were used: mastoid obliteration, CWD mastoidectomy, chronic otitis media, and cholesteatoma. The limiting search terms were the synthetic materials. Additional articles were identified by hand searching the reference lists of the retrieved articles.

We initially identified the papers based on their title, limited their number based on their abstract, and finally on the basis of the whole document. Two authors (C.S. and P. K.) independently classified the articles that were eligible. Any difference was resolved by consensus.

The literature was analyzed regarding the type of filler material used, the rate of extrusion/ complications, and the effectiveness of each type of mastoid obliteration. This was based on the postoperative assessment of complications, the shape of the external auditory canal as described in each study, and the improvement of hearing.

Statistical Analysis

All the computations needed were processed by the RStudio program (RStudio Team, 2015, RStudio: Integrated Development for R. RStudio, Inc., Boston, MA). The overall rate of rejection of the used synthetic material was computed by dividing the number of cases with extrusion by the total number of cases.

RESULTS

We included 15 articles that described patients who underwent mastoid obliteration with synthetic materials. The initial search using the term "mastoid cavity obliteration" brought in 244 citations, of which 145 did not meet the inclusion criteria and 48 were not published in English. An additional 38 articles were excluded because they reported mastoid obliteration with natural materials. The remaining 13 studies were included in the review (Figure1). The use of search terms and the manual search yielded two additional studies. Thus, the total number of articles meeting the inclusion criteria increased to 15 (Table1) [6, 7, 10-22]. All papers were included in a retrospective case series.

Type of Synthetic Material

The material most authors used for the obliteration of the mastoid is bioactive glass (9/15 studies). S53P4 was the type of BAG that seven of these authors applied. Bioactive glass ceramics were chosen for use in two studies. The second most widely used material was hydroxyapatite, either in the form of a cement or in the form of granules (3 out of 5 studies). Other filling materials were hydroxyapatite, titanium, and silicone. Some authors used a combination of biological and artificial materials.

Effectiveness (Efficacy)

As mentioned above, the evaluation of the effectiveness of mastoid obliteration was based on the postoperative assessment of complications, appearance of the external auditory canal contour, and the improvement in hearing. In the present review, the overall rate of rejection of the used synthetic material was quite low (3.5% with a range of 0-15.8 %); the study showing 0% rejection rate included

Table 1. Summary of articles on mastoid obliteration and associated synthetic materials in mastoidectomy surgery procedures

Study(Year)/ Number of patient	Material	Operation	Follow Up	Complications (apart from rejection of material)
Sorour [6] (2018)/ 20	BAG (S53P4)	PMW Reconstruction in CWD	12-36 months	Persistent otorrhea: 2 (10%)
Elbary [10] (2018)/20	TitaniumMicromesh	PMW Reconstruction in CWD	12-36 months	0
Mestdagh [11] (2017)/ 67	BAG (S53P4)	MO in CWD	12-54 months	Cholesteatoma recidivism: 4 (6%)
Vos [12] (2017) /23	BAG (S53P4)	MO in CWD & CWU	2.4 Years	Persistent otorrhea: 6 (26%)
Bernardeschi [13] (2017) /41	BAG (S53P4)	MO in CWD & CWU	1 Year	Granulation tissue: 1(2.4%)
Ezzat [14] (2014)/40	BAG (45S5)	MO in CWD	2 Years	Persistent otorrhea: 6 (15%) Cholesteatoma recidivism: 4 (10%)
Lee [7] (2013)/20	HA	MO in CWD	1 Year	Retraction pocket: 1 (5%) Infection: 1 (5%)
Silvola [15] (2012)/16	BAG (S53P4)	MO in CWD	2.2 Years	Infection:4 (25%)
Shokry [16] (2012)/20	BAG (45S5)	MO in CWD	6 Month	Infection: 2 (10%) Cartilage extrusion: 1 (5%)
Sarin [17] (2012)/25	BAG (S53P4)	MO in CWD	34,5 week	Prolonged healing: 2 (8%) Postoperative vertigo and pain: 1 (4%)
Cho [18] (2012)/20	Silicone	PMW Reconstruction & MO in CWD	6-90 Months	0
Park [19] (2011)/30	HA	PMW Reconstruction & MO in CWD & CWU	6month	Persistent otorrhea: 3(10%) Granulation tissue: 6 (20%)
Stoor [20] (2010)/7	BAG (S53P4)	MO in CWD	12-98 Months	Granulation tissue: 1 (14%)
Kakigi21 (2008) /10	HA - calcium phosphate paste		MO in CWD	19.9 Months 0
Ridenour22 (2008) /3	HA	MO in CWD	2 y	0

vBAG: Bioactive glass; CWD: Canal wall down; CWU: Canal wall up; HA: Hydroxyapatite; MO: Mastoid obliteration; PMW: Posterior meatal wall

only 20 patients (Table 2). Patients treated with hydroxyapatite were the most high-risk group for extrusion (15.8%). Apart from the rejection of the used material, the most common complication of mastoid obliteration was persistent otorrhea (10-25%). Other reported complications include occurrence of infection (25%), persistent granulation in the posterior canal wall (2.4-20%), retraction pocket formation (5%), and postoperative vertigo and pain (4%). In two studies, a high rate of cholesteatoma recidivism was reported (6% and 10%).

DISCUSSION

Herein, we looked into the use of synthetic material for mastoid obliteration and its current state in the literature. The available level of evidence is low (3), consisting of retrospective case series and limited clinical reports. The limited number of publications is the main reason for this. So far, however, the use of synthetic material in mastoid obliteration appears an established way of dealing with cavities with relatively low complication rates. Our study did not compare biological with synthetic products; as such comparisons would have been very challenging and potentially of meaningless/low-evidence conclusions. Still, it provides an up-to-date overview of the efficacy of synthetic material.

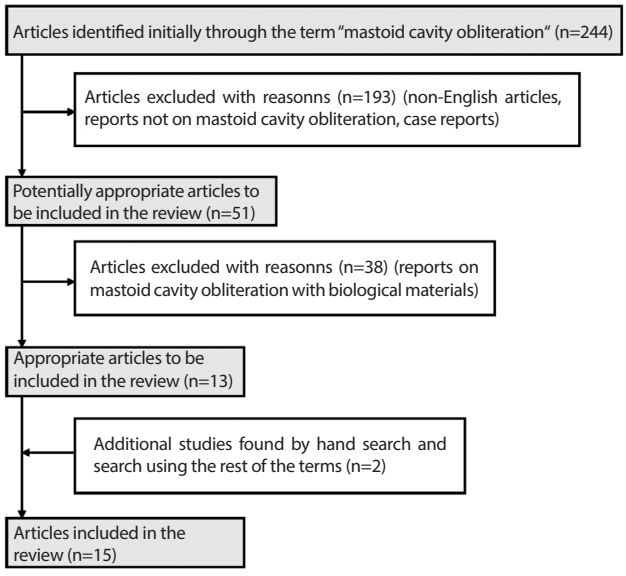

Figure 1. Flow chart of the reviewing process.

Generally, in canal wall up mastoidectomy, the anatomy of the posterior canal wall is preserved avoiding recurrent infections and eliminating the need for recurrent cavity cleaning. However, this surgical technique is associated with a high recurrence rate (36% in adults and 67% in children) [1, 23]. However, CWD mastoidectomy has numerous advantages, including less operative time and lower recurrence and residual rate. For all these reasons, it is the most widely used surgical intervention for treatment of cholesteatoma worldwide [24]. A large mastoid bowl after CWD mastoidectomy can be associated with a number of complications, such as recurrent drainage and infection, water intolerance, calorically induced vertigo and others; [1] thus, patients may suffer a substantial loss of quality of life. Surgical techniques used for management of an open mastoid cavity after CWD mastoidectomy include obliteration (cavity fill-in) and reconstruction (canal wall defect repair). The obliteration method includes filling the mastoid cavity with various biological (fat, bone chips) or synthetic materials (bioactive glass, hydroxyapatites, titanium, or silicone).

The use of biological materials is associated with several drawbacks, namely, long-term follow-up has showed that some soft tissues, such as free muscles, fat, and fascia flaps tend to undergo atrophy, retraction, and fibrosis. This leads to a progressive loss of the obliterating material over time. Thus, the final shape and size of the mastoid cavity cannot be predicted. That is why some authors recommend overfilling of the mastoid cavity. Another limitation of autogenous materials is the fact that it is difficult to have an adequate amount of them available. Moreover, harvesting an autologous graft increases the duration of surgery and the morbidity rate. Finally, autogenous obliteration materials are associated with donor site morbidity. Various artificial materials have been introduced to compensate for the limitations of autografts.

Table 2. Summary of the type of synthetic materials used for mastoid obliteration and percentage of rejected materials

Material/Trade Naμe/Company	Authors/No patients/ Cases of rejected material	Total cases for each material	Total cases of extrusion
BAG (S53P4)/Bon Alive/ Bon Alive Biomaterial LDT (Turku, Finland)	Sorour [6] 20/0 Mestdagh [11] 67/0 Vos [12] 23/0 Bernardeschi [13] 41/0 Silvola [15] 16 /0 Sarin [17] 25/1 Stoor [20] 7/0	199	1 (0.5 %)
BAG 45S5/CERAVITAL/. (Ernst Leitz, Wetzlar, Germany; Xomed, Jacksonville, Fla)	Ezzat [14] 40/2 Shokry [16] 20/0	60	2 (3.3%)
Hydroxyapatite (HA) or β-tricalcium phosphate and polyphosphate (β-TPP)/PolyBone/Mimix ® Kyoungwon Medical Co., Seoul, Korea	Lee [7] 20/1 Park [19] 30/6 Kakigi [21] 10/0 Ridenour [22] 3/3	63	9 (15.8%)
TitaniumMicromesh,/-/JEILmedical corporation, Seoul, Korea	Elbary [10] 20/0	20	0 (0%)
Silicone/-/Hansbiomed Co., Daejeon, Korea)	Cho [18] 20/1	20 362	1 (5%) 13 (3.5%)

BAG: Bioactive glass; HA: Hydroxyapatite; β-TPP: β-tricalcium phosphate and polyphosphate

Type of Synthetic Material

To date, numerous synthetic materials have been proposed for the obliteration of the mastoid cavity. The material most authors used is bioactive glass (BAG) [6, 11-17, 20]. It is one of the latest synthetic biomaterials that combines several advantages. Several BG types have been tested and each type presents different properties in vivo [25]. S53P4 and 45S5 are the two main BAGs that have been studied in vivo [26]. S53P4, named after its chemical composition of 53% SiO_2 and 4% P_2O_5, has the property of not shrinking after obliteration. This is important for retaining an anatomically suitable volume in the obliterated area. Although BAG S53P4 is a resorbable material, it does not resorb before new bone has formed. On the other hand, 45S5 is characterized by a significantly faster resorption rate. S53P4 possesses antibacterial properties that minimize the risk of infection and decrease the extrusion of the mastoid filler. Munukka et al. [27] demonstrated that BAG S53P4 has a significant bactericidal effect on 29 clinically important aerobic bacteria, including methicillin-resistant *Staphylococcus aureus*. Likewise, Leppäranta et al. [28] found that BAG S53P4 had a strong growth-inhibitory effect on 17 anaerobic bacteria. The safety of using BAG as mastoid filler material has been well established in several studies. Other convincing arguments in favor of the use of BAG are its osteoconductive and angiogenesis promoting properties.

Another widely used biomaterial as a bone substitute is **Hydroxyapatite** (Ca10(PO4)6(OH)2). The mineral composition of hydroxyapatite (HA) is similar to that of bone [19]. It can be classified into two categories, namely Synthetic HAP and Coralline HA. HA can be used in the form of granules, cements, and other bone implants. The main advantages of this alloplastic material are good biocompatibility, good osteoconductive properties, and direct chemical bond formation with hard tissues [29]. However, the use of HA cement as a mastoid filler is associated with several complications, such as infection, severe osteitis, and delayed osseointegration [30]. An impermeable and avascular implant is at risk for foreign body reaction in the presence of any infection, even if it is delayed. On the other side, granules might be a reasonable obliteration material. It is their abundant porous structure that allows them to absorb antimicrobial solutions before implantation and allow vascular ingrowth in situ [22]. Additionally, a calcium phosphate paste was used for mastoid obliteration because of its biocompatibility and osteoconductivity. It fits into cavities of various sizes and enables minimally invasive surgery. The β-tricalcium phosphate and polyphosphate (β-TPP)/ Polybone is a kind of HA. It is available in two forms: granular and powder. It contains an osseointegration factor that stimulates the differentiation of osteoblasts and increases the expression of bone morphogenetic protein-4. Animal experiments demonstrated that new bone formed around obliterated Polybone and showed successful osteointegration [7]. In addition, Polybone causes nearly no inflammation due to its high biocompatibility. Granular Polybone produces less inflammatory reaction in comparison with the powder type. Although Polybone is considered a relatively safe and effective mastoid filler, the literature describing its otologic use is limited.

Silicone is widely used in otosurgery (ventilation tubes, cochlear implants, and ossiculoplasty prostheses). It is considered to be a safe material, as there is no evidence of immunotoxic response. Silicone blocks are flexible enough to handle and are suitable for different sized cavities. Moreover, they are strong enough to prevent breakdown in the mastoid. In addition, their cost is much lower than other alloplastic materials. However, the use of silicone may lead to a foreign body reaction [18].

Finally, **Titanium** is a synthetic material that has been also used for the management of the persistent mastoid bowl. It has been proven to be biocompatible. It also has the property of osseointegration with bone. In addition, a titanium mesh is a pliable material, so it can be easily shaped according to the surgical requirements [10].

Effectiveness and Complications

Evaluation of the effectiveness of mastoid obliteration is based on the postoperative assessment of complications, the incidence of extrusion, and the appearance of the external auditory canal. Numerous studies have shown good results with the use of BAG S53P4. The overall incidence of extrusion in this therapy group was found to be 0.5%. Sorour et al. [6] assessed the results of posterior meatal wall reconstruction after CWD mastoidectomy using S53P4. In all patients, the reconstructed ear canal was smooth without hidden pouches, irregularities, or stenosis. No foreign body reaction, extrusion, and/or displacement of the BAG material were found. Statistical analyses revealed significant hearing improvement. Mestdagh et al. [11] investigated the efficacy of S53P4 as filler material in 67 cholesteatoma patients who received mastoid obliteration surgery. An acceptably dry ear was achieved in 96% of all cases. Silvola et al. [15] reported a case series of 14 patients who underwent mastoidectomy and cavity obliteration with S53P4. All the ears became dry and one ear was overfilled and required meatoplasty. Sarin et al. [17] presented a retrospective case series that included 26 patients. Excluding two patients with only 1 month of follow-up, 96% of the cases had a dry, safe ear or only intermittent ear discharge. In 92% of the patients, a smaller or nonexistent cavity was achieved. Stoor et al. [20] treated six patients with radical cavities by using BAG S53P4 as a filling material. The mastoid cavities decreased in size in all cases. None of the patients had infections associated with BAG.

Regarding the use of BAG 45S5, the existing reports are quite positive. Ezzata and Eid performed a retrospective observational study with 40 patients. Postoperative ear discharge was found in only six patients (15%) and recurrence or residual cholesteatoma was found in four cases (10%) [14]. Shorky et al. [16] evaluated BAG 45S5 in 20 patients, where infection occurred in two cases but was readily controlled by topical application of antibiotics.

Although hydroxyapatite is the second most widely used filler material for mastoid obliteration, its use does not seem to yield good results. In contrast to BAG, the overall incidence of extrusion was found to be 15.8%. Park et al. [19] examined the rate of graft failure and complications in three groups of patients sorted according to the graft material (autogenous bone, allogeneic bone, and HA). The rate of graft failure was 20% in HA group, 3.1% in allogenic bone group, and 0.8% in the autogenous bone group. Ridenour et al. [22] reported that the use of hydroxyapatite cement as an obliteration material in three pediatric patients was associated with disappointing outcomes, as all three cases required revision surgery to remove the HA cement. According to Kakigi et al. [21], calcium phosphate paste covered with artificial dermis and soaked with b-FGF was likely to be useful for the management of an open mastoid cavity. All 10 patients in their study demonstrated decreased volume of the mastoid bowl within two months without any recurrent discharge. Lee et al. [7] assessed the effectiveness of β-tricalcium phosphate and polyphosphate (β-TPP) as a mastoid filler in 20 patients with chronic otitis media by performing intact canal wall mastoidectomy or simple mastoidectomy. No bone resorption was demonstrated in the obliterated mastoids.

Cho et al. [18] were the only authors who evaluated the efficacy of mastoid obliteration with silicone blocks. They performed a retrospective evaluation of 20 patients. In 19 cases (95%), the postoper-

ative appearance of external auditory canal was found to be smooth and the tympanic membrane healed without perforation. In only one case (5%), the rebuilt canal wall was destroyed due to tympanic membrane perforation. Statistical analyses revealed significant improvement in hearing.

Elbary et al. [10] were the only authors who used titanium mesh and platelet-rich plasma mixed with bone pate for the reconstruction of PMW. All patients showed apparently normal PMW contour. No complications were reported.

Generally, most of the identified studies included a small number of enrolled patients and were of retrospective in nature. Additionally, the follow-up period was usually short, with the surgical outcomes being assessed by the surgeons themselves. These factors carry a significant level of bias and conclusions should be interpreted very cautiously, particularly when it comes to potential complications, the lack of which in some studies has made the scientific community wary. We cannot comment on the use of autologous materials, as this was not our goal.

CONCLUSION

Mastoid obliteration with synthetic materials seems to be a safe and effective therapeutic option for the management of an open mastoid cavity. BAG is the most researched and most reliable synthetic material for mastoid obliteration. HA carries the highest risk for a foreign body reaction. Finally, given the low level of evidence, prospective studies with a long follow-up and a more robust setting are required to look into synthetic and biological materials for mastoid obliteration.

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REFERENCES

1. Mehta RP, Harris JP. Mastoid obliteration. Otolaryngol Clin North Am 2006; 39: 1129-42. [CrossRef]
2. Chan CY, Chan YM. Mastoid obliteration and reconstruction: a review of techniques and results. Proc Singap Healthc 2012; 21: 23-9. [CrossRef]
3. Alves RD, Cabral Junior F, Fonseca AC, Benito RF. Mastoid obliteration with autologous bone in mastoidectomy canal wall down surgery: a literature overview. Int Arch Otorhinolaryngol 2016; 20: 76-83. [CrossRef]
4. Leatherman BD, Domhoffer JL. The use of demineralized bone matrix for mastoid cavity obliteration. Otol Neurotol 2004; 25: 22-6. [CrossRef]
5. Peltola M, Aitasalo K, Suonpää J, Varpula M, Yli-Urpo A. Bioactive glass S53P4 in frontal sinus obliteration: a long-term clinical experience. Head Neck 2006; 28: 834-41. [CrossRef]
6. Sorour SS, Mohamed NN, Abdel Fattah MM, Elbary MEA, El-Anwar MW. Bioglass reconstruction of posterior meatal wall after canal wall down mastoidectomy. Am J Otolaryngol 2018; 39: 282-5. [CrossRef]
7. Lee HB, Lim HJ, Cho M, Yang SM, Park K, Park HY, et al. Clinical Significance of β-Tricalcium Phosphate and Polyphosphate for Mastoid Cavity Obliteration during Middle Ear Surgery: Human and Animal Study. Clin Exp Otorhinolaryngol 2013; 6: 127-34. [CrossRef]
8. Jang CH, Cho YB, Bae CS. Evaluation of bioactive glass for mastoid obliteration: A Guinea pig model. In Vivo 2007; 21: 651-5.
9. El-Seifi A, Fouad B. Long-term fate of plastipore in the middle ear. ORL J Otorhinolaryngol Relat Spec 1998; 60: 198-201. [CrossRef]
10. Elbary MEA, Nasr WF, Sorour SS. Platelet-Rich Plasma in Reconstruction of Posterior Meatal Wall after Canal Wall Down Mastoidectomy. Int Arch Otorhinolaryngol 2018; 22: 103-7. [CrossRef]
11. de VeijMestdagh PD, Colnot DR, Borggreven PA, Orelio CC, Quak JJ. Mastoid obliteration with S53P4 bioactive glass in cholesteatoma surgery. Acta Otolaryngol 2017; 137: 690-4. [CrossRef]
12. Vos J, de VeyMestdagh P, Colnot D, Borggreven P, Orelio C, Quak J. Bioactive glass obliteration of the mastoid significantly improves surgical outcome in non-cholesteatomatous chronic otitis media patients. Eur Arch Otorhinolaryngol 2017; 274: 4121-6. [CrossRef]
13. Bernardeschi D, Pyatigorskaya N, Russo FY, De Seta D, Corallo G, Ferrary E, et al. Anatomical, functional and quality-of-life results for mastoid and epitympanic ob-literation with bioactive glass s53p4: a prospective clinical study. Clin Otorhinolaryngol 2017; 42: 387-96. [CrossRef]
14. Ezzat AE, Eid MI. Evaluation of using Bioglass in obliteration of mastoid cavity. Curr Sci Int. 2014; 3: 87-94.
15. Silvola JT. Mastoidectomy cavity obliteration with bioactive glass: a pilot study. Otolaryngol Head Neck Surg 2012; 147: 119-26. [CrossRef]
16. Shokry S, Al'Sayed H, Zidan MF, Hafez Aa, Abdulsalam HM. Avoiding mastoid cavity Problems: Mastoid obliteration using Bioactive glass. The Egyptian Journal of Hospital Medicine 2012; 47: 321-33.
17. Sarin J, Grénman R, Aitasalo K, Pulkkinen J. Bioactive glass S53P4 in mastoid obliteration surgery for chronic otitis media and cerebrospinal fluid leakage. Ann Otol Rhinol Laryngol 2012; 121: 563-9. [CrossRef]
18. Cho SW, Cho YB, Cho HH. Mastoid Obliteration with Silicone Blocks after Canal Wall Down Mastoidectomy. Clin Exp Otorhinolaryngol 2012; 5: 23-7. [CrossRef]
19. Park JS, Kang MY, Hong JC, Park BG, Kang MK. Result of Mastoid Obliteration According to the Graft Materials: Autogenous Bone, Allogeneic Bone, Hydroxylapatite. J Int Adv Otol 2011; 7: 305-10.
20. Stoor P, Pulkkinen J, Grenman R. Bioactive glass S53P4 in the filling of cavities in the mastoid cell area in surgery for chronic otitis media. Ann Otol Rhinol Laryngol 2010; 119: 377-82. [CrossRef]
21. Kakigi A, Taguchi D, Takeda T. Mastoid obliteration using calcium phosphate bone paste with an artificial dermis soaked with basic fibroblast growth factor: preliminary clinical report. Auris Nasus Larynx 2009; 36: 15-9. [CrossRef]
22. Ridenour JS, Poe DS, Roberson DW. Complications with hydroxyapatite cement in mastoid cavity obliteration. Otolaryngol Head Neck Surg 2008; 139: 641-5. [CrossRef]
23. Shohet JA, de Jong AL. The management of pediatric cholesteatoma. Otolaryngol Clin N Am 2002; 35: 841-51. [CrossRef]
24. Hulka GF, McElveen JT. A randomized, blinded study of canal wall up versus canal wall down mastoidectomy determining the differences in viewing middle ear anatomy and pathology. Am J Otolaryngol 1998; 19: 574-8.
25. Andersson OH, Karlsson KH, Kangasniemi K. Calcium phosphate formation at the surface of bioactive glass in vivo. J Non Cryst Solids 1990; 119: 290-6. [CrossRef]
26. Della Santina CC, Lee SL. Ceravital Reconstruction of Canal Wall Down Mastoidectomy. Long-term Results. Arch Otolaryngol Head Neck Surg 2006; 132: 617-23. [CrossRef]
27. Munukka E, Leppäranta O, Korkeamäki M, Vaahtio M, Peltola T, Zhang D, et al. Bactericidal effects of bioactive glasses on clinically important aerobic bacteria. J Mater Sci Mater Med 2008; 19: 27-32. [CrossRef]
28. Leppäranta O, Vaahtio M, Peltola T, Zhang D, Hupa L, Hupa M, et al. Antibacterial effect of bioactive glasses on clinically important anaerobic bacteria in vitro. J Mater Sci Mater Med 2008; 19: 547-51. [CrossRef]
29. Munjal M, Passey J, Agarwal A, Meher R. Hydroxyapatite Granules For Mastoid Cavity Obliteration: A Study Of 25 Cases. The Internet Journal of Otorhinolaryngology 2004; 3: 1-4. [CrossRef]
30. Mahendran S, Yung MW. Mastoid obliteration with hydroxyapatite cement: the Ipswich experience. Otol Neurotol 2004; 25: 19-21. [CrossRef]