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STUDIES ON MASTOIDPLASTY USING AUTOGENOUS BONEMARROW AND FREE SKINGRAFT

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ABSTRACT

The mastoid cavity after "débridement" becomes one of the main causes of failure in the follow-up of tympanoplasty when left unobliterated. Various trials have been made to seek an effective method of filling up the cavity.

We conducted a study on mastoidplasty using autogenous bonemarrow and free skingraft and found the results were satisfactory. 15 patients were observed clinically, histologically and radiographically. We observed survival of cancellous bones and free skingraft taking in the cavity, and perfect obliteration was obtained.

Successful mastoid operation in patients with perfect obliteration leads to a conclusion that the most reliable and safe treatment consists of complete excision and obliteration of excavated portions.

Audiometric observation could not clarify to what extent the mastoid operation would affect hearing of high pitched sounds.

It is evident, therefore, that this obliteration method is of more value in obtaining better results on the processes after mastoid operation than in improving hearing acuity to high pitched sounds.

INTRODUCTION

Efforts to minimize formation of mastoid cavity after tympanoplasty are aimed not only to faciliate post-operative treatment but also to obtain better results in the follow-up of mastoid operations. When the excised mastoid cavity remains open to the external auditory canal, voluminous crust will remain in the cavity. In cases of dead angle formation, it will cause inconvenience in examining or cleaning of the mastoid cavity.

Under these conditions, the mastoid cavity offers a suitable site for fungi or organism to propagate, causing dermatitis or erosion which will perforate the tympanic membrane if the case becomes grave.

Therefore, an unobliterated mastoid cavity often will result in failure of tympanoplasty which is primarily aimed at diminution of aural discharge and

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improvement in hearing acuity. Thus the treatment of mastoid cavity has caused much concern among otolaryngologists.

Certain treatment has been tried to protect the posterior wall of the external auditory canal in order to prevent the cavity to go thru it, but this method does not always guarantee recovery to the original shape of the canal by protection of skin alone.

In consideration of the fact that there are more cases needing obliteration, such as when no wall exists, or in such case where complete removal of the wall is needed, it would be more reasonable to undertake obliteration with some effective materials.

In view of the above reasons, we made a clinical study to find an effective method of obliteration along with some additional matters.

Obliteration materials presently used are reported in the table below.

TABLE 1. Materials for Obliteration of Mastoid Cavity.

Muscle:	(pedicle, free)
	M. sternocleidomastoideus.
	M. temporalis.
	M. auricularis superior.
Fat:	Fat from the back of ear, or from abdomen.
Cartilage:	Autogenous cartilage. Cattle cartilage.
Bone:	1) Autotransplant
	Bonemarrow etc.
	2) Heterotransplant (Sheep, Cattle)
	Kielbone etc.
Synthetic resin:	Methyl methacrylate.

The use of autogeneous bone was attempted as we believed a most natural healing effect would be obtained if we used the same kind of bone to fill the cavity.

We intended in this study not only to observe survial of cancellous bone in the cavity but also to see whether the free skingraft covering the transplanted bone shows good epithelization. Since Goto's tympanoplasty is characterized by the use of free skingraft for formation of tympanic membrane and external auditory canal, we directed our effort primarily toward the use of these materials.

To achieve the above objective, we conducted postoperative clinical, histological and radiographical observations and tested the effect of mastoid operation on hearing acuity.

CLINICAL OBSERVATION

10 male and 5 female patients ranging from 11 to 41 years were clinically

TABLE 2. Fifteen Cases with Grafting of the Mastoid Cavity.

Case No.	Name	Age	Sex	Disease	Size of mastoidcavity	Condition of mastoid bone	Results of mastoidplasty
1	T.I.	32	M.	Left chronic otitis media	Wide	Osteomyelitic	success
2	T.S.	26	M.	〃 〃	〃	〃	〃
3	M.H.	19	M.	〃 cholesteatoma	Narrow	Sclerotic	〃
4	K.W.	20	F.	Right 〃	〃	〃	failure
5	Y.M.	11	F.	Right chronic otitis media	Wide	Osteomyelitic	success
6	T.S.	26	M.	Right cholesteatoma	〃	Sclerotic	failure
7	Y.K.	19	M.	Left chronic otitis media	〃	Osteomyelitic	success
8	T.T.	20	M.	R. Recurrence after operation	Medium	Sclerotic	〃
9	M.O.	21	F.	L. chronic otitis media	Narrow	〃	〃
10	M.Y.	20	M.	R. Rec. after operation	Wide	Osteomyelitic	failure
11	M.O.	21	F.	R. Chronic otitis media	〃	Sclerotic	success
12	K.O.	21	F.	R. Cholesteatoma	Narrow	〃	〃
13	S.K.	21	M.	R. Rec. after operation	Wide	Osteomyelitic	〃
14	M.N.	41	M.	L. Chronic otitis media	Medium	Sclerotic	〃
15	B.I.	30	M.	〃 〃 〃	〃	〃	〃

observed.

Bonemarrow of the iliac crest of patients was used for obliteration. The process is as follow: Periosteum of iliac crest is exposed by cutting 3 cm of the upper skin and then cut into 1×2 cm rectangular form, removing the cortex of the bone with chisel. Cortex is kept in physiological saline solution. Or, in some cases the cortex is cut open in valviform leaving the periosteum, and the necessary amount of bonemarrow is taken out with a sharp spoon. Bonemarrow cavity is injected with 250 mg of Sigmamycin intravenous. Then the cortex is returned to original place, and iliac crest osteoplasty is performed.

The application of antibiotic chemical was effective in preventing occurance infection of the iliac crest and was further useful in preventing apearance of hematoma or swelling, believed inherent to post-operation.

Pieces of bonemarrow kept in Sigmamycin solution were cut into $1 \sim 2$ mm slices with a scissor and filled into mastoid cavity. A piece of free skingraft was used as cover in order to form the tympanic membrane and external auditory canal.

The term "bonemarrow" which is used in this paper has to be explained. Bonemarrow transplantation for obliteration of mastoid cavity applied in our study is different fundamentally from myelocyte insertion for tretment of aplastic anemia. Our bonemarrow transplantation is somewhat similar to bone grafting preferably used in orthopedic surgery.

It is admitted that myelocyte insertion also aims at transplanting myelocyte and reticular tissue which support the bonemarrow.

In consideration of the important role that substantia spongiosa plays in the reconstruction of post-operation, it should be called "substantia spongiosa transplantation" rather than bonemarrow transplantation. However, we will use simply the term "bonemerrow" in this paper.

Now, returning to chemotherapy with antibiotic substance, 750 mg. Sigmamycin was drip infused during operation, and for 3 days after operation, the patients were treated with 250 mg. Sigmamycin, or Terramycin injected intravenously 3 times a day.

After three days, the patients were given orally 250 mg×4 (1,000 mg.) Sigmamycin for two weeks until the external auditory canal becomes dry.

15 cases of mastoidplasty by bonemarrow transplantation observed showed in general good response to operation as shown in table 2. Recovery status after operation is prescribed below.

During the early post-operation stage, we observed serous sanguineous exudation around the cortex, but two weeks later we observed dryness and found no exudation.

After two years, retraction of the rear wall of the external auditory canal was slight, which indicated success of the primary objective, and assured the effectiveness of this method.

However, Schiller *et al.* state "free skin grafts used to cover any of the bone strip do not survive", and contradicts the result of our study.

Such a discrepancy might be due to the fact that they used larger size bonemarrow strips, while we used smaller ones which permit epithelization of skingraft as it will allow sufficient growth of granulation.

However, among 15 cases we experienced three cases (20%) of failure, the causes of which were examined and were as follow.

Seven days after operation, cases No. 4 and 10 developed erosion in the skin forming the posterior wall of the external auditory canal which finally became perforated. The cause of these failures is presumed to be due to the use of a larger strip of bonemarrow which damaged the free skingraft, then infected the skin leading to putrefaction of the bone. In these two cases, however, we observed clear evidence of circumspection of infection when we found surving bone surrounded by fresh granulation few millimeters ahead.

Good granulation and epithelization were obtained soon after the removal

of the infected portion and a very slight depression was observed at the rear wall of the canal. We recommend the use of "Terracortril" ointment, preparation of oxytetracycline HCl and hydrocortisone, in these cases since we obtained good results when we applied the drugs to the surface of the wound with a gauze.

Case No. 6 is another example of perforation. In this case too much pressure employed when inserting the bone into the cavity might be responsible for the erosion and perforation of the skin in the canal. The bone strip tightly put into the cavity would expand in size due to secreting fluid from the wound, and bulge irregularly into the external auditory canal to break the skingraft transplanted. We tried obliteration again after scraping away the putrid bone, and succeeded.

Considering the above three cases of failure, we may conclude that the reasons for failure are

(1) the use of larger size bone with sharp edges which perforated the skingraft, and

(2) the expansion of the bone after pressure insertion which bulged to break the skingraft.

In all the cases secondary infection caused bone necrosis at the surface.

Therefore, there is need to use a smaller bone strip, and at the same time to insert them without too much pressure.

From our past experience, we knew that bone necrosis, seen in the worst cases, do not go deeply into the tissue, so it could be recovered by removing the portion infected and application of Terracortril ointment.

Narrower canal can be obtained even in cases scraping is needed if we obliterate the mastoid cavity. We experienced that successful result can be guaranteed if obliteration is conducted after mastoid operation. Mastoid osteoplasty is an operation worth trying, and is especially valuable after radical mastoidectomy and in cases when no posterior wall exists in the external auditory canal.

Also, there is possibility of epithelization of the free skin graft.

The use of living substance, autogeneous bone, will give the patient much benefit, compared with the use of artificial material like Kielbone, in preventing infection by organisms, since living substance will possess resistance to infection.

HISTOLOGICAL OBSERVATION

Histological observation is needed to support the clinical results stated above, so a small piece of bonemarrow which was obliterated in the cavity was taken as material.

Removal of small pieces from the obliterated bonemarrow did not affect

the operated portion. We decalcified the sample, and stained with haematoxylin-eosin according to the Azan-Mallory method for microscopic study.

Histological observation of bonemarrow showed a composition as illustrated in Fig. 1, consisting of the osteoplaque, bonemarrow cell and fat tissue.

Three weeks after operation, the transplanted components of hematopoietic tissue showed rapid decrease, but juvenile granulation with capillary vessel was seen growing. It was not solid but showed no round cell infiltration.

After one month, the juvenile granulation developed to become a part of the skingraft, as shown in Fig. 2. Nuclei of the cells in the epidermis covering the cavity existed, and formed histological combination with the granulation. The above result indicates that after one month the transplanted bonemarrow, excepting osteoplaque, was replaced by living connective tissue which adhered closely to the skingraft. It may be considered that a possibility exists for the transplanted bonemarrow to shrink and after some time to disappear due to absorption.

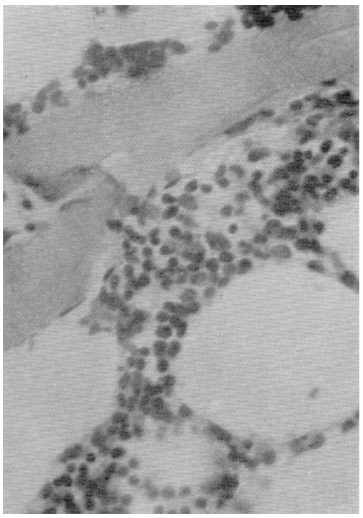

Fig. 1

Fig. 2

However, in the clinical follow-up we did not find any shrinkage or absorption of bonemarrow. Therefore we conducted histological studies on a long term basis, the results of which are illustrated in Fig. 3. Two years after operation, we found fibrous granulation tissue in the form of solid cicatrization. The osteoplaque which plays a major role in obliteration changed its original shape but contrary to our assumption it showed no signs of absorption around the bone, and the condition of the tissue was stable. We presume from the

above facts that the obliterated portion would continue to be in a stabilized condition without any substantial changes, since there was neither osteoclast nor perialienitis observed histologically.

From the histological observations conducted for a long period, we may assume safety and effectiveness of the operation.

As stated above, we could confirm survival of the bonemarrow and free skingraft after mastoidplasty.

We believe mastoidplasty using bonemarrow free skingraft would be safe and effective for cases where there is no posterior wall in the external canal or when filling in of the gap after operation is needed, irrespective of the size of the cavity. The best result would be achieved by conducting mastoidplasty when physicians find difficulty in deciding whether trepanation of mastoid cavity is necessary or not, or when they hesitate doing so for fear that it would extend the mastoid cavity by operation.

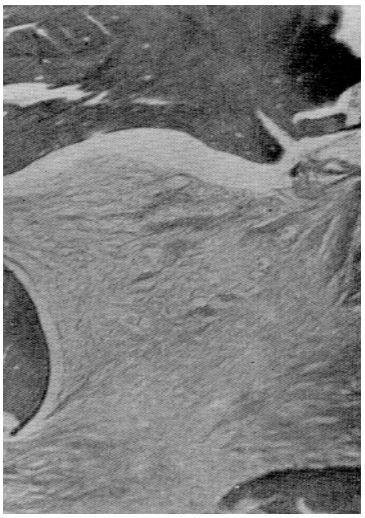

Fig. 3

Obliteration with bonemarrow and skingraft would save the patient from recurrence, or at least it would extend the mastoid cavity by operation.

Obliteration with bonemarrow and skingraft would save the patient from recurrence, or at least it would warrant greater safety than not operating which may lead to infection.

RADIOGRAPHICAL OBSERVATION

We conducted radiographic observations on transplanted bonemarrow according to lapse of time.

Radiographs of the patients were taken periodically one, three, six and twelve months after mastoid osteoplasty by Sonnenkalb, Stenvers and Mayer Methods.

Most typical variation was found in a 26 year old patient, case No. 2, in the left ear, radiographed by the Sonnenkalb Method, as illustrated below.

Fig. 4. shows a variation after one month. The mastoid cavity shows uniform shadow which prevents clear distinction from the surrounding bones. This indicates obliteration of the mastoid cavity was made intimately by the bone marrow inserted.

There is an indication of direct conjunction between the transplanted bone-

Fig. 4

Fig. 5

marrow and the wall of the mastoid cavity. At the time and immediately after operation, the bonemarrow in the cavity received its nutrition from the liquid medium of the serum component, and was gradually connected with the cavity wall by means of increasing granulation with capillary vessels. In the radiograph taken after six months (Fig. 5), there is clearly seen concentration of shadow in the center. X-ray transparent, semi-lunar substance is observed around the center, but no distinct boundary between bones and the substance

Fig. 6

is recognizable. That is, there was seen a concentration of the bonemarrow which shrinks to form a cicatrization.

Along with such concentration, we also observed growing granulation around the wall of the surrounding bone.

Twelve months after operation, the radiograph (Fig. 6) shows a marked demarcation between transparent and thick portions in the mastoid cavity.

Transparency may be considered to indicate formation of a hollow in the cavity. The above is a typical case illustrated radiographically, and if we arrange the 7 cases of radiographs into a table, they are as shown in table 3.

In the seven cases, except one, we observed a diffuse shadow in the cavity at an early stage of recovery from operation. After three to six months we observed a transparent part around the shadow which became discernible after twelve months in contrast with the density in the center. The above observation contradicts Schiller's report which states: "0 to 3 months: Grafts are clearly discernible because of their increased density. 3 to 6 months: The grafted area becomes more rarefied, and the individual grafts less defined. From six months on: The grafted area increases in density and eventually is indistinguishable from the surrounding host bone." In our observation experienced one case similar to Schiller's case.

In case No. 9, the cavity was seen covered with a uniform shadow after 6 months and indistinguishable from the surrounding host bone. However, the other 6 cases presented a distinguishable semi-lunar shadow of X-ray transparency. We presume the difference in results to be due probably to the size of bone used, but a more positive proof for justification is needed.

As has been stated, we recognized the formation of a hollow in the cavity in most of the cases, though, we did not observe any retraction at the posterior wall of the external canal.

Observation of a dense shadow in the cavity twelve months after operation may also prove radiographically the exisence of a bone bridge even after a long lapse of time, which, along with histological results, is believed to be evidence of the permanent existence of bone in the mastoid operated cavity.

TABLE 3. List of Post-operative Varations (7 cases) Radiographed

Case No.	One month	Three months	Six months	Twelve months
1	Mastoid cavity covered with uniform shadow.			Clear demarcation around the center.
2	Mastoid cavity with diffuse shadow. Vague distinction.		Diffuse shadow in the middle. With Semi-lunar transparent portion.	Clear demarcation Transparency.
6		Behind cavity is transparent, others are covered with diffuse shadow.	Semi-lunar, transparent portion is recognizable.	Semi-lunar and other portions can be clearly distinguished.
7	Cavity covered with shadow. some dens.		Transparent in some parts.	Clear demarcation possible.
9		Sharp contrast. Clear Demarcation.	Uniform shadow. No clear demarcation.	
10			Semi-lunar transparent part recognizable.	Clear demarcation
11	Covered with uniform shadow.		Sharp contrast in the center. X-ray transparency fair.	

AUDIOLOGICAL OBSERVATION

We conducted audiometric examinations to see whether mastoidosteoplasty will produce better results in hearing acuity after operation. 15 cases of audiograms after operation were studied for comparison with average hearing powers before operation, which were calculated mathematically by the formula,

$$\frac{500 + 2 \times 1000 + 2000 \text{ cps}}{4}.$$

We experienced 10 cases with improved hearing acuity of more than 5 db.,

TABLE 4. Hearing Acuity in Speech Range, Pre- and Post-operation $\left(\frac{500+1000\times2+2000\text{cps}}{4}\text{db}\right)$

(1) Cases of improvement

C/No.	Hearing acuity before oper. (db)	After oper. (db)	Increase (db)
2	46	37	9
3	57	47	10
4	40	26	14
5	58	46	12
9	54	39	15
10	53	41	12
11	39	34	5
13	49	29	20
14	52	33	19
15	40	25	15

(2) Minor improvement

7	25	21	4
8	53	51	2
12	62	60	2

(3) Failure

1	28	Scale out	
6	49	81	—32

3 cases of below 5 db, and 2 cases of failure. (Table 4)

Of two cases of failure, case No. 1 showed heavy infection of the bone indicating necrosis, with only the stapes remaining and buried in thick granulation, the malleus and incus were missing. Various operations were carried out to examine the mobility of the footplate of the stapes which also remained, but during the process, the patient developed labyrinthitis and lost his hearing power.

Another case (C/No. 6) showed loss of the footplate of the stapes due to cholesteatoma.

When removing this cholesteatoma, the vestibular fenstra was opened, and the formation of columella with fascia failed to cause recovery of hearing acuity.

Of three cases with minor improvement in hearing power of under 5 db, case No. 8 had received radical mastoidectomy 8 years ago, but due to continuous aural discharge, the patient was operated again.

The footplate was missing, and the vestibular fenestra in the form of a membrane was recognized.

Formation of columella with periosteum did not improve hearing acuity. In another case with cholesteatoma leaving only stapes, that was attached to

the surrounding tissue preventing movement, no recovery of hearing acuity was found. In case No. 7 we found a highly edematous tympanum mucous membrane forming polypi, but the movement of the incudo-stapedial joint was sufficient to maintain the incus and stapes. Incomplete curettage made at the tympanic cavity and the attic resulted in perforation of the tympanic membrane, and hearing acuity did not return.

Except case No. 11 which was treated by tympanoplasty type I operation, all which showed improvement were operated by type III method. There were 2 cases of cholestearoma and 1 case of re-operation. The average improvement in hearing acuity was 13 db.

Hypacusis of high tone is frequently found in patients after tympanoplasty. There are considerably a large number of otolaryngologists who believe the excavation in the external canal is responible for hardness of hearing. Goto *et al.* made an audiological study on variation of hearing threshold using a model, and reported a large size excavation in the mastoid may cause decrease of sound pressure.

Gomi noted 122 cases (29.3%) with decrease of hearing in high tone but the majority of these also showed loss of hearing power in low and middle tones. She stated only 8 patients with difficulty of hearing in high tone instead of improvement in other ranges of sound. She also stated that various operational procedures of the auditory ossicle or excavation of the mastoid cavity hardly produced a adverse effects on auditory acuity of high tone clinically. Disturbance in hearing can be gradually removed after formation of a newly reconstructed tympanic membrane.

She conducted cochlear microphonic guiding examination on guinea pigs by covering the perforated tympanic membrane with an artificial substance made of plastic, or by plastering the auditory ossicle to the hinder movement of the auditory ossicle.

She stated, after reviewing the results of examination, that reduction of tenseness of the auditory membrane would decrease hearing acuity not only for high tone but also for lower tone.

She presumed hardening with plaster of Paris, clinical appearance of hard granulation are responsible for decreasing high tone hearing. She also stated that even if it is difficult to define the reason for hearing reduction by one factor, a major cause is dependent upon the characteristic of the new tympanic membrane.

Audiometric study of our cases (the result of which was shown in Table 5) after operation was analyzed into 6 cases of poor result, 5 of improvement, 1 of scale out and 4 unchanged. It would be improper to conclude the cause of lowering of hearing acuity by such few number of cases, but at least we may claim it improper to expect maintenance of hearing power by not excavating

TABLE 5. Change of Hearing Acuity for High Tone. (Pre- and Post-operation)

$\left(\frac{6000+8000 \text{ cps}}{2} \text{db}\right)$

	C/No.	Pre-oper. (db)	Post-oper. (db)	Increase (db)
Improved	2	50	18	32
	8	53	48	5
	10	45	40	5
	13	60	50	10
	15	50	30	20
Unchanged	3	Scale out	Scale out	
	5	25	28	−3
	6	65	68	−3
	14	53	50	3
Aggravated	1	35	Scale out	
	4	23	45	−22
	7	45	53	− 8
	9	33	50	−17
	11	28	50	−22
	12	38	50	−12

the cavity.

We presume the superiority of tympanpolasty exists in prviding better results after operation than recovery of hearing acuity for high tone.

CONCLUSION

Based on 15 cases of mastoidplasty and histological and radiographical observations, we confirmed "Take" of bonemarrow and skingraft transplanted into cavity. The survival of the obliterated materials also proved that any size of mastoid cavity can be filled. In the light of this, we believe the obliteration method we employed to be worth undertaking, unless the surgeon dislikes the work of taking a bonemarrow.

Even in case where there is difficulty in deciding excavation, surgeons should undertake radical removal of the infected mastoid cells. Such a radical operation will give the patient better chance of not suffering recurrence of the disease.

However, we culd not ascertein the effectivness of this mastoidplasty in maintaining hearing acuity for high tone, from audiometric study.

This operation is of more value in assuring better results, of progress after operation than of preserving high tone hearing acuity.

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