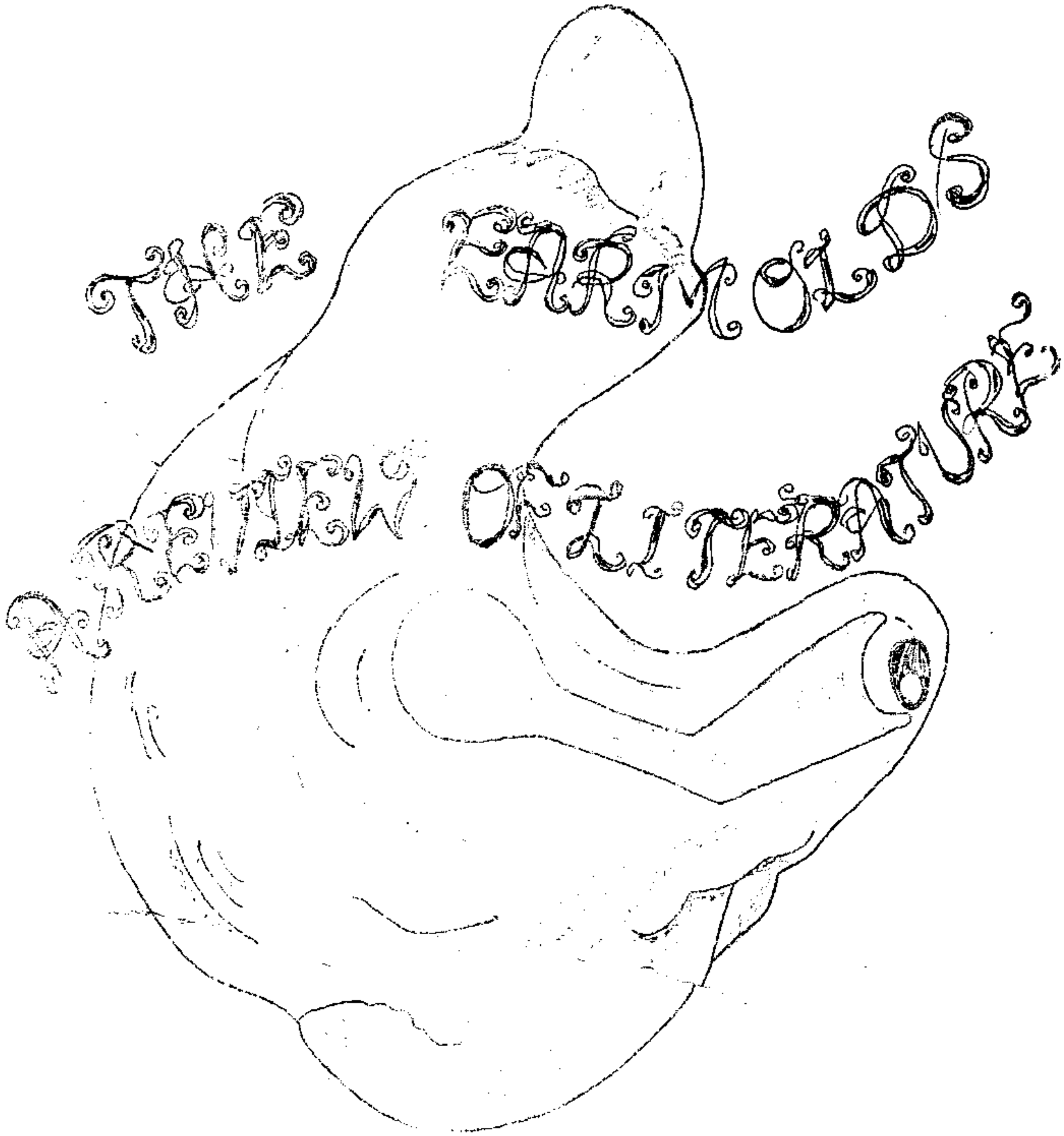

REG.No.8803

AN INDEPENDENT PROJECT SUBMITTED AS PART FULFILMENT FOR FIRST YEAR M.Sc. (SPEECH AND HEARING) TO THE UNIVERSITY OF MYSORE

ALL INDIA INSTITUTE OF SPEECH AND HEARING: MYSORE-570006

MAY 1989

TO ALL LOVERS OF AUDIOLOGY

Who have in any way

contributed to its spread and progress

&

THOSE CLINICIANS

Who, In the rehabilitation of the hearing impaired

have been influenced

BY A DIVINE SENSE OF HUMANITY

than any sordid consideration of lucre

this project is dedicated to

as a token of

RESPECT AND ADMIRATION.

CERTIFICATE

This is to certify that the Independent Project : " THE EARMOLDS - A REVIEW OF LITERATURE " is the bonafide work in part fulfilment for the degree of M.Sc, (Speech and Hearing) of the student with Register number 8803.

Director
All India Institute of
Speech and Hearing
Mysore-6

Mysore
May 1989

CERTIFICATE

This is to certify that this Independent Project entitled ' THE EARMOLDS -A REVIEW OF LITERATURE " has been prepared under my supervision and guidance.

Dr.M.N.Vyasamurthy
Guide

DECLARATION

I hereby declare that this Independent Project entitled "THE EARMOLDS -A REVIEW OF LITERATURE" is the result of my own study under the guidance of Dr.M.N.Vyasamurthy, Lecturer in Audiology, All India Institute of Speech and Hearing, Mysore-6, and has not been submitted earlier at any University for any other Diploma or Degree.

Mysore. Register Number 8803

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TABLE OF CONTENTS

CHAPTER-I
INTRODUCTION

'Science moveS bUt slowly,
Creeping en item point to point'

- Tennyson.

In the lines of Audiology that is expansive, science fostered, science fostering and world conquering, the field of earmolds toe haS bean undoubtedly extensive, spanning the fields of acoustics, mathematics, electroacoustics and material sciences.

A sound hearing is a vital, everyday link with the world. In the drama of life,one seldom gives it a second thought. It is when an auditory loss is incurred that we realize how important this is to us and how difficult life can be without this vital sense of hearing.
Necessity is the mother of invention.
Breaking this'isolated ward of sound of silence' to the 'world of resound', the miracle of modern medicine and technological advancement, coupled with the deligence of the professional has created new avenues for better hearing. The field of earmolds is one such, fostering the physical cum acoustic needs of the ears.

Earmold, sometimes called the earpiece, is a plastic insert designed to conduct the amplified sound from the hearing aid receiver into the ear canal as efficiently aa possibles Langford, 1995.

Forming a constituent part of the personal amplification system, it serves to -

1) link the hearing aid to the patient, confirming to the external ear contours.
2) convey the sound from the output transducer of the hearing aid (receiver) to the external auditory meatus.
3) among many others, another vital role is the acoustic modification of the output signal which are beyond the circumscription of the electrical modifications of the hearing aid.

With this background, the present pages, founded on the researcher's valiant effort to solve the mystery of how to best fit the ears (physical + acoustic) requiring differential consideration, deals with the following:

- Earmold nomenclature (NAEL).
- The earmold options commercially available including the physical style options, the modular hearing aid models, non-occluding, antifeedback and acoustical options.
- Acoustic modifications grossly comprise of the principles of venting, dampers and horn effect, exercising control over low, mid and high frequencies respectively, taking into account the ease of handling, cosmetic and comfort consideration and acoustic seal.

The consecutive chapters deal with the technological aspects of fabricating a good earmold (impression and processing), its maintenance and repair in the dispensers office, the importance of custom mold in hearing aid selection procedure. Finally, another major determinant of user satisfaction which can make or marr a successful usage of earmold - the fitting of the mold is dealt with.

Earmold technology continues to be dynamic, and yet, the manufacturers have been slow to exploit this vast reservoir of practically baaed knowledge. The reason for this is perhaps not felt to be within their province and does not seem to be commercially applicable. This being an integral part of the amplification system, it is our responsibility to marshall the professions intellectual capabilities and prelude to a manifesto that we meet this with a challenge.

CHAPTER-2

EARMOLD-THE ESSENTIAL ARMAMENTARIUM OF PERSONAL AMPLIFICATION SYSTEM

"Earmold, sometimes called the earpiece, ia a plastic inaert designed to conduct the amplified sound from the hearing aid receiver into the earcanal as efficiently as possible" - Langford, 1975

It forms an integral part of the personal amplification system extending its influence on fitting of the hearing aid to the acoustic modifications which are beyond the circumscription of electrical controls of the hearing aid.

Role of earmolds:

Various roles of earmolds have been cited in literature (by the authors quoted in bibliography) which are as follows:

(i) It forms a link between the hearing aid and the patient (Nolan and Tucker, 1985).

(ii) It is mechanically and acouatically designed to deliver the amplified signal with controlled modifications, i.e. it ia the conveyor of sound from the output transducer of the hearing aid (the receiver) to the external auditory meatus.

(iii) It serves to anchor the ear-level hearing aids, affording retention of the aid to the ear. For the body aids, the earmold provides a retainer for the receiver.

(iv) The earmold has a very significant influence on the frequency response of a hearing aid (Lybarger, 1967; Curran, 1978, Corell, 1978, Skinner, 1988 and others).

(v) It provides aa acoustic real to prevent auditory feedback for the high gain aids (particularly the custom mold). But this is often considered the 'weak link' in the amplification chain owing to the fact that 'the quality of fit of the mold in a child's ear may give rise to the problem of acoustic feedback' (Nolan et al, 1978).

(vi) The quality of fit often determines the usable gain of the hearing aid.

Earmold configuration:

The earmold configuration confirms to the anatomical landmarks of the external ear and ia said to represent reverse of the ear. These principle parts, together with the corresponding location on the earmold are represented in Fig-1.

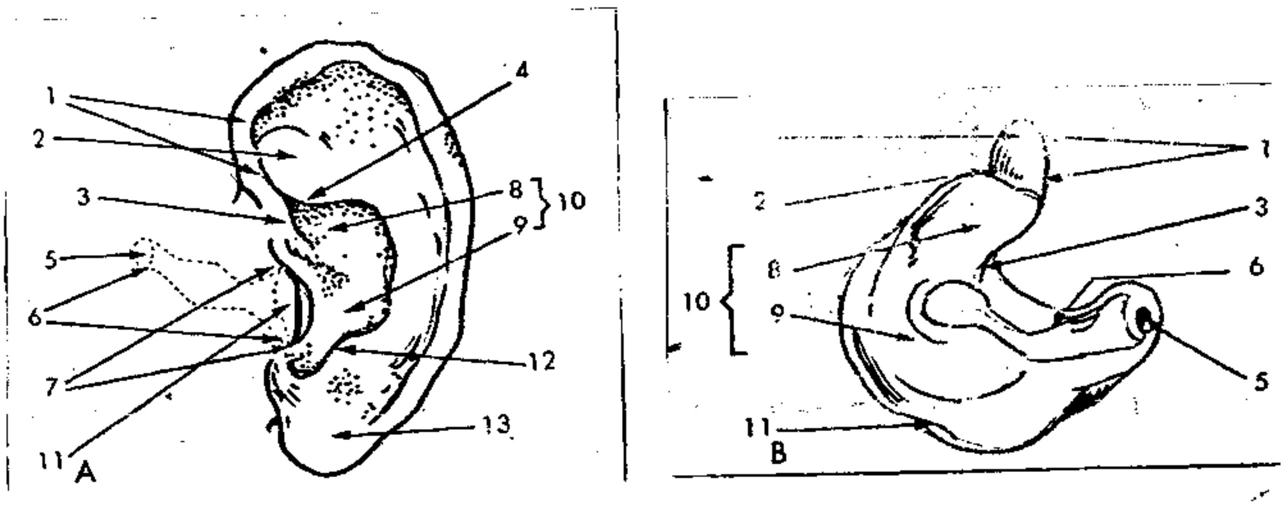


Fig.1: External ear and its principle parts. **The earmold**

1. Helix 2. Fossa 3. Crus 4. Antihelix 5. Tympanic membrane 6. External auditory meatua 7. Aperture 8. Canba 9. Cavum 10. Concha (Bow) 11. Tragus 12. Anti-Tragus 13. Lobule (lobe).

Nomenclature for specific parts of the earmold:

The National Association of Earmold Laboratories (NAEL) 1970, proposed the following nomenclature for earmold configuration baaed onthe anatomical landmarks of the external ear.

Fig.2: The propoaed NAEL anatomical landmarks.(RECEIVER MOLD)

Canal : The part of the earmold that is inserted into the ear canal.

Concha rim: The part of the earmold that extends from the canal to the helix and fits in the concha of the ear.

Bridge : That portion of the earmold extending from the canal to the junction of the concha rim and the helix.

Helix : That portion of the earmold adjacent to the helix of the ear.

Bowl : That part of a shell earmold covering the bowl of the ear (The term bowl is unfamiliar, bat probably refers to that region of the ear described anatomically as the cavum concha.

Heel : That part of the earmold lying between the tragus and the antitragus.

Receiver base : That part of the earmold on which the base of the receiver rests.

Sound bore : The hole extending through the canal to the tubing connection or the receiver nub.

Flare : A funnel shaped enlargement of the sound bore at the end of the canal.

Vent : Any hole giving free passage to air to the sound bore of the earcanal.

Refraining from the usage of diverse terminologies as currently being employed by earmold manufacturers, a standard system of nomenclature for various parts/aspects of earmold ia likely to eliminate confusion and difficulty in obtaining earmold with the characteristics necessary for the amplification system (Zachman et al, 1970).

Requirements of an earmold:

Earmold is an integral part of the wearable hearing aid system, the acceptance of which requires confirmation to certain criteria, meeting both the client's and the professional's demands. These requirements as listed out by Tucker, Nolan, and Colelough, 1978 and Tucker, Nolan, 1984 include:

1. Client's demands
2. Professional's demands.

Clients demands:

(i) Good cosmetic acceptability.

(ii) Comfort - Unsightiness or discomfort resulting from an earmold may be seized on by the reluctant possessor of a hearing aid as an excuse for not using an instrument.

(iii) Good acoustic fit - With high gain aids, acoustic feedback imposes a limit on the usable gain and can be a source of embarrassment to the user and his acquaintances; a well fitting earmold eliminating or alleviating its likelihood.

(iv) Good physical fit - Adequate retentive capability reduces the risk of hearing aid slipping from the ear& being damaged or lost.

(v) Ease of insertion and removal.

(vi) Ease in cleaning.

(vii) It should not interfere with normal facial movements.

Professional's demands/wants:

In addition to the above, an ideal mold should be -

(i) A reliable product,

(ii) Should not shrink.

(iii) Base of working ia essential.

(iv) It should have a quick processing time.

(v) Should be formed directly in the ear (one-stage process) owing to the minimization of delay in making the finished product. This is particularly of importance for children, being deprived of an efficient amplification for the two to eight weeks required for processing a two-staged acrylic mold (INSTANT - IDEAL CONDITION).

(vi) It should avoid the cumulative errors of acoustic leakage inherent in the two-stage process.

(vii) Should be capable of handling high acoustic output.

(viii) Compatible with commercial hearing aids.

(ix) Constructed from standard available material.

With this background, we shall now look into the different commercially available earmold options.

CHAPTER-3

EARMOOLDS THEN AND NOW

Hearing is a vital link of man to the communicating world, and the hearing impaired is robbed of this vital experience. In his guest for a more efficient sound, the field of earmolds has seen a proliferation of the fitting options within a span of time between 1949 to 1989.

"From 1949 to 1985, the dispensing community has seen a number of earmold fitting options in the area of physical shape,acoustical options, tubing options and earmold fabrication materials increase from a simple few choices to now more than 90 options. The result of this growth at the dispenser level has been confusion..." Mynders, 1986.

In the present section, the earliest known custom earmolds and the options available currently, pooled up from the review of literature is discussed at length.

The earliest known custom earmolds:

Berger (1981) in a review on the earliest known custom earmolds reports -

" A few references to the introduction of custom earmold date from 1920s or 1930s. The first electric (carbon) hearing aid employed an earphone; and in the 1920s and 1930s, a trend began of replacing the earphones with smaller devices - the receivers. The first receiver used with electrical hearing aids employed wood or hard rabber eartips, so as to direct the amplified sound into the earcanal more efficiently. The receiver and eartip were typically held at the ear by a wire which was wrapped over the pinna. Soon custom and stock earmolds appeared.

The introduction of custom earmolds, however, dates back well before the 1920s. At least three confirmed instances of custom earmolds can be dated before the present century, obviously being used with non-electric hearing devices. The device was invented by Friedrich Wilhelm Aschendorf. The Aschendorf hearing aid cone was made of thin silver, but whether the earmold was made of silver or of another material was not clear. However, it is clear that a cast was made of the patient's concha as the model for the earmold portion.

(Fig.3: Picturizes the Aschendorf hearing aid and earmold)

A second use of a custom earmold dates from about the same time as that by Aschendorf; this Loewe device is picturized in fig.3B and 3C. This consisted of a lacquered papier mache or metal concha portion, modeled from a cast of the ear concha, with central opening continuous with the auditory canal. Again, the specifies of how the earmold was made are unknown. To the earmold was attached a large, stiff paper disc which fit over the side of the head.

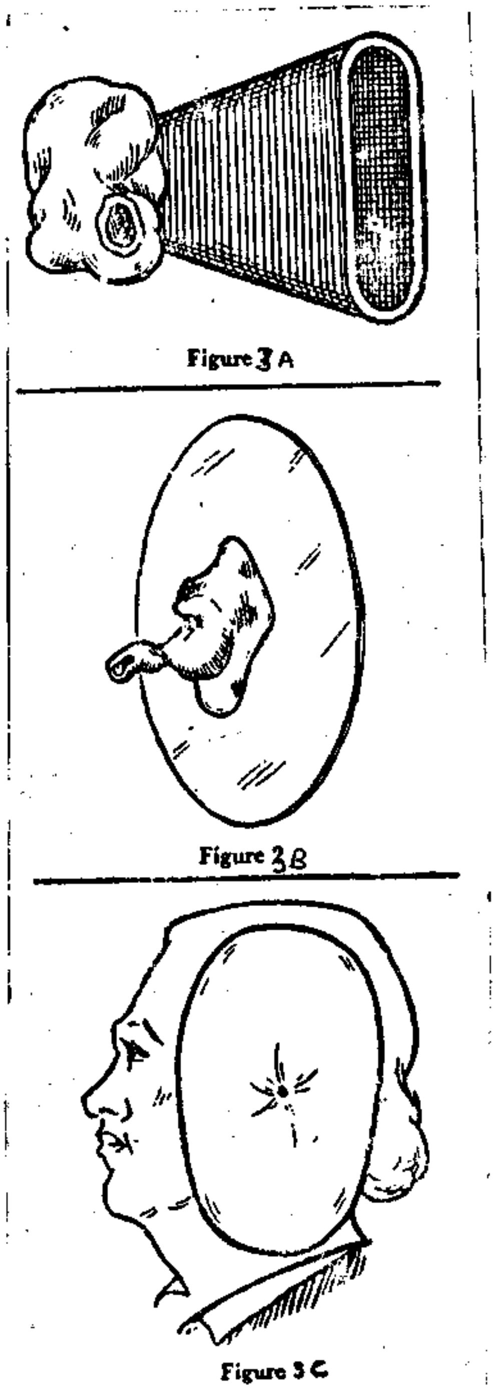


FIG.3: THE EARLIEST KNOWN CUSTOM EARMOLDS.

The third pre- twentieth century use of custom earmoldS were those made as early as 1890 by Thomas Hawksley. The earmolds was made a wax impression of concha and slightly inward into the external canal, by using Stents dental modeling. When the impression had been made and excess wax trimmed off, it was coated with metallic powder , and placed in an electrolyte depositing bath of copper sulfate, with a bar of copper as an anode. A thin coat of copper was thus deposited over the impression and When it was sufficiently thick the wax melted oat and the pure copper surface smoothed and polished.

Earmolds for electric aids:

The first patents for earmolds were obtained in 1926 by Halsey Augustus Frederick. Frederick Patent (No.l, 601, 063) was assigned to Western Electric Co. The same firm obtained patents for four sizes of right and four sizes of left stock earmolds soon thereafter (Nos. 1, 668, 890 and 1, 668, 910).

This called for an earmold made of gutta-percha, rubber compound or plastic. It was suggested that the material might be made to resemble the flesh of the user; though flesh-coloured earmolds were made only after 1940s.

The earmolds for Western Electric Co. were made under license by the S.S.White Dental Manufacturing Co. for several years, with a price to hearing aid manufacturers and distributors of $10 less 30%. They were made of black vulcanite.

Dentistry played an important part in the manufacture and perfection of custom earmolds. The S.S.White firm made the earliest known custom earmolds for use with electric hearing aids. Efforts to improve custom earmolds as well as to describe their acoustic effect on the amplified signal were made by Dr.Mayer, B.A.SChier, a dentist in New York, owner of Crypto-plastics Laboratory, a manufacturer of custom earmolds. Other pioneer manufacturer of custom earmolds were M.L.Muir, Inc; of New York, H.D. Justi and Sons, Inc., of Philadelphia, and the Sonotone Corp."

Earmold nomenclature - proposed by NAEL:

The National Association of Earmolds Lab (NAEL), in 1970 proposed a system of classification dealing with the nomenclature of specific landmarks of the earmold (as already discussed) and a system dealing with the specifications of the earmold types. This nomenclature has its basis on the aforementioned anatomical landmarks and the physical characteristics of the earmold. This includes -

1. Skeleton: Consists of the canal, complete concha rim and bridge and may include the helix (Fig.4A) .
2. Three-fourths skeleton: Same as the earmold described above but with the central portion of the concha rim removed (Fig.4B).
3. Semiskeleton: Consists of the canal, bridge and helix without a concha rim.
4. Canal: Consists of the canal portion only.

5. Canal lock: Consists of the canal with one-half of the concha rim present. (Fig.4.C)
6. Shell: Consists of the canal and a thin shell covering the bowl of the ear. This earmold may or may not include a helix (Fig.4.D).
7. Half shell: Same as shell but with the bowl extending only half way to the helix.

Direct couple earmolds:

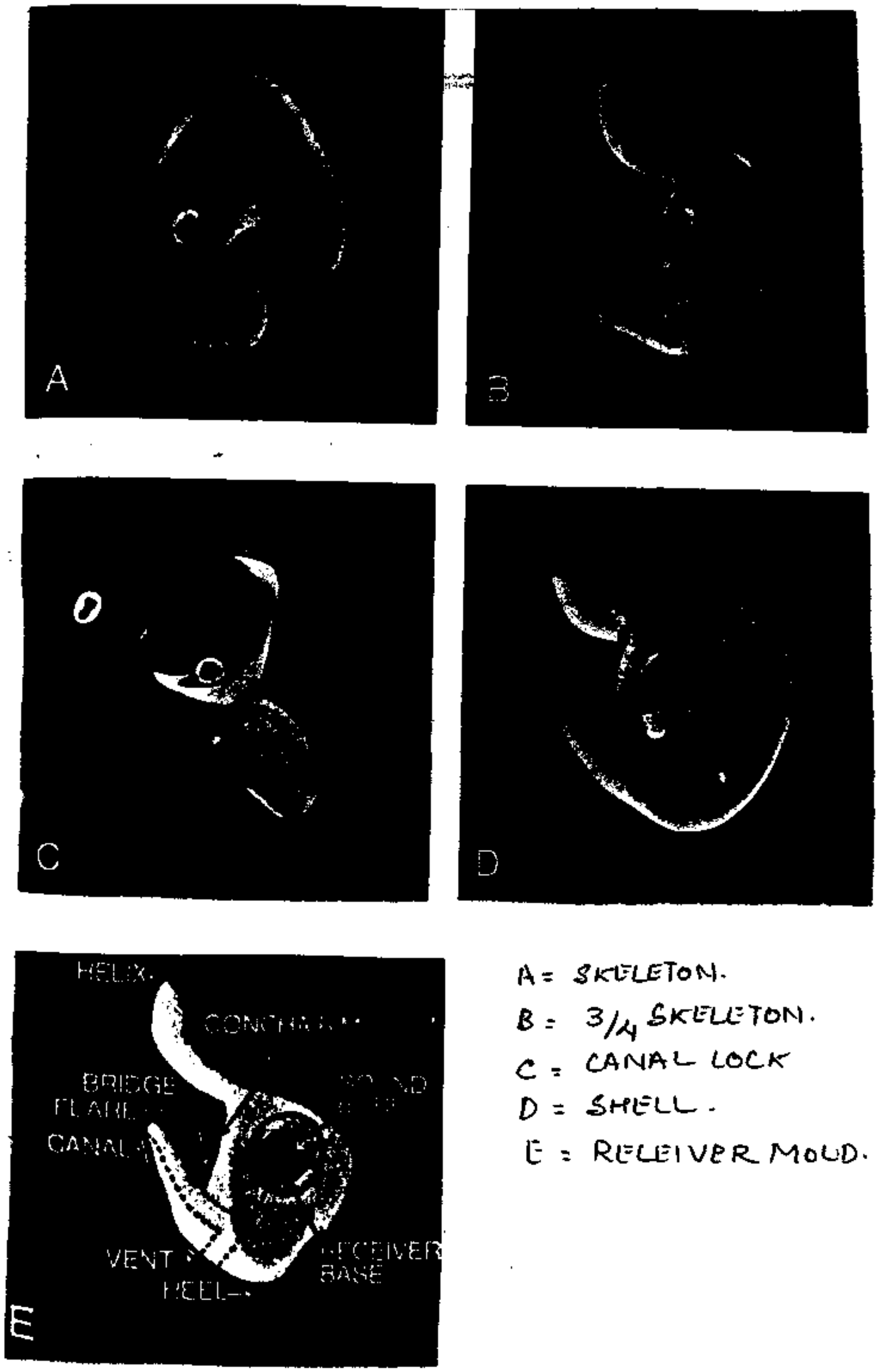
Receiver - full solid mold with the meatal snap ring or other attachment to hold a receiver directly onto the earmold (Fig.4.E).

All-in-the-ear: Designed to hold the insert hearing aid in the ear.

Although NAEL has proposed a standard system of terminology, they minimize its effectiveness by stating that the nomenclature is not affered to "preclude the use of trade names but rather serve to supplement them".

Usage of NAEL proposed nomenclature for earmolds:

Zachman et al, 1970: conducted a survey comparing the NAEL proposed system and that currently used by the earmold manufacturers. Eight earmold manufacturers were sampled for the survey.



A = SKELETON.
B = 3/4 SKELETON.
C = CANAL LOCK
D = SHELL.
E = RELEIVER MOLD.

Fia.4: Earmold nomenclature - NAEL

Results indicated that the terms 'standard', numerical classification of = 1', 'regular' etc were utilized for the term 'receiver'; numerical listing, silhouette, hyda-mold and phantom for'skeleton', etc. which did not coincide with the proposed nomenclature.

The implication is the need to bridge up this disparity by operating on a standard system of nomenclature for earmold types and various aspects of earmold like bore length and diameter, vent length, diamter and placement so as to eliminate confusion throughout the professional spectrum dealing with the hearing impaired.

The currently available options can be broadly categorized into -

1. Physical style options.
2. Modular hearing aid models.
3. Non-occluding options.
4. Antifeedback options.
5. Acoustical style options.

I.Physical style options:

1. Receiver mold: This is a full, solid mold with a metal of plastic snap ring for the appropriate sized nubbin to hold the receiver directly onto the earmold. This mold is designed to set as deeply

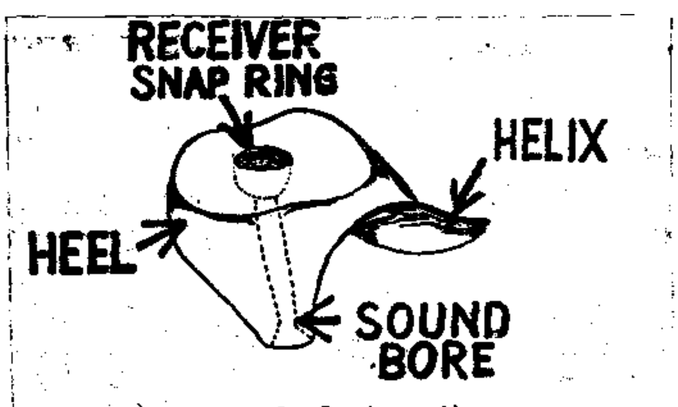


FIG. 5 : RECEIVER MOLD.

into the ear as the diameter of the receiver will permit. It can be used with both body level and ear-level hearing aids with an external receiver. The above figure depicts the receiver mold. It can also be used with a BTE with internal receiver if a male adaptor is used; can be converted into the tragus mold for preventing acoustic feedback.

2. Shell mold: This is the earmold used for hearing aids with internal receivers. With or without helix, its use is dictated when fitting high gain ear level aids. Its acoustic properties are similar to those of the standard earphone-coupled mold, but physically, all its possible bulk is removed from the bowl ensuring comfort.

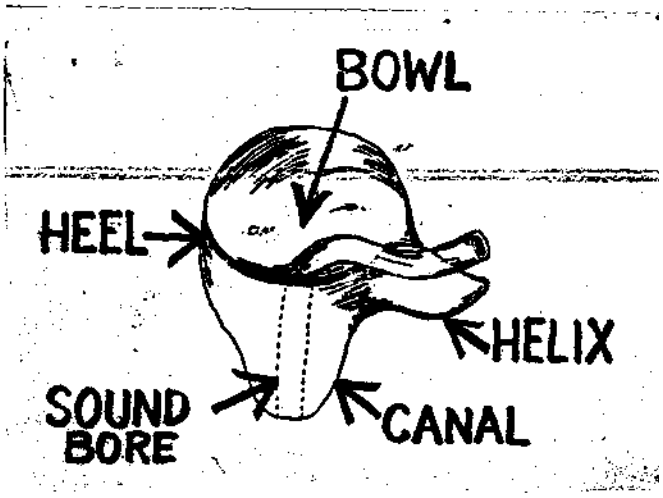


Fig.6A: Shell mold.

It has a full canal and a thin shell covering the bowl of the ear. Tight seal and thick walled tubing is necessitated in lieu of the acoustic feedback. Modification includes the half-shell mold.

Half shell mold is the shell mold with helix portion removed. This mold is often successful with geriatric patient who have difficulty inserting the shell mold (Fig.6B)

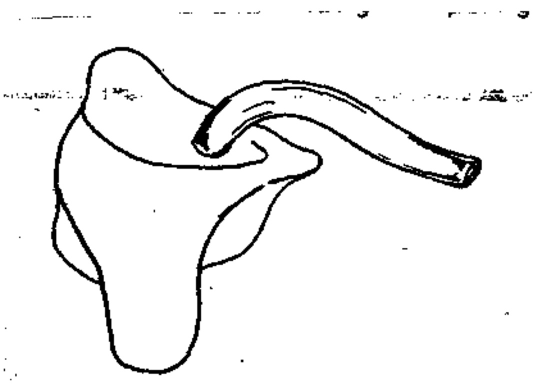


FIG-6B - HALF SHELL

3. **Perimeter or skeleton earmold:**

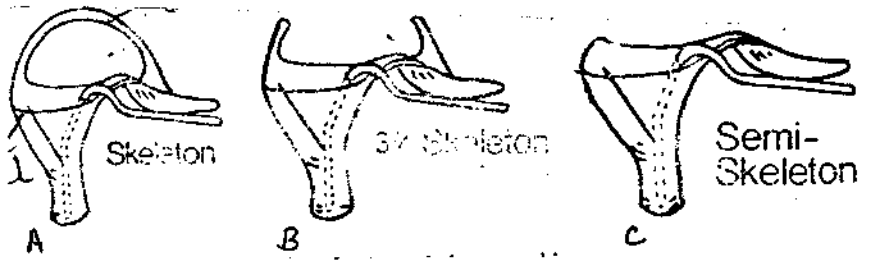


Fig.7A SKELETON **B** 3/4 SKELETON **C** SEMI - SKELETON

This is used with post auricular and eyeglass hearing aids. It is similar to the shell mold except that the center portioa of the concha has been hollowed out, leaving only the rim. It offers more comfort to the wearer owing to the increased air circulation in the concha when compared to the shell mold. This is used with moderate gain instruments and is adaptable to the short canal, open Sore fitting, as the concha rim sustains the mold in the ear. The mold has a standard tubing of constant diameter which opens into a large, hollowed-out sound bore. Canal is short. A medium sized (for eg. 1.5 mm) vent running parallel to the tubing also opens into the sound bore. This can be fabricated with tubing of a constant internal diameter (ID) that ends at the tip of the mold or with a stepped-bore IB such as the libby horn. The earmold tip can be long (14.2 mm), medium (8.8 mm) or short (4.4 mm) (Lybarger, 1985), and the length and ID of venting can be varied. The body of the skeleton mold has less balk than the standard earmold and more than an open earmold. The mold offers two variations, as depleted in figure 7B and 7C.

1. The 3/4 skeleton - this also retains the acoustic characteristics of a standard mold. In this, the centre pact of the concha rim is removed for added comfort. Retention of the mold is not usually a problem; but for very small pinnae, its use may be contraindicated.
2. Semiskeleton mold - this is a skeleton mold with the concha rim removed. The mold is easier to inset for patients with dexterity problems. Others have difficulty in inserting it owing to missing anatomical landmarks and lack of orientation of the mold in the appropriate direction.

4. Canal mold: The mold contains the canal portion only; used with mild to moderate gain instruments. Advantages of this mold pertain to the ease of insertion, comfort and maximum cosmetic appear. This should be used only when the details of the earcanal will ensure its retention. It does not usually provide sufficient seal for use with severe hearing losses, though at times, may be successful with them also. "This

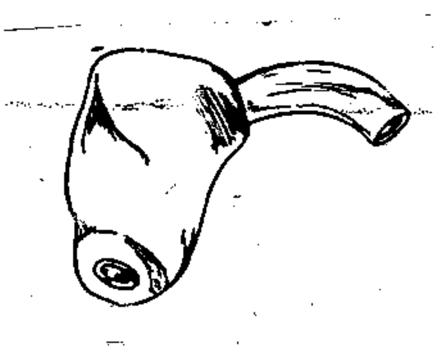


Fig.8: Canal mold

earmold often results in retention problems and feedback. Use of this mold is not recommended" - Hodgson, 1977.

5. **Canal lock mold:** This is the most recommended mold for moderate gain instruments, consisting of a canal plus the lower one-half of the concha rim. The rim permits retention for small or straight canals and is also an aid in the insertion and removal of the mold from the ear. (Fig.9)

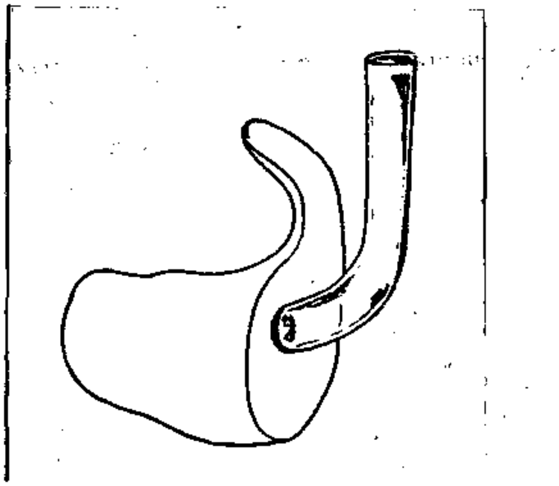
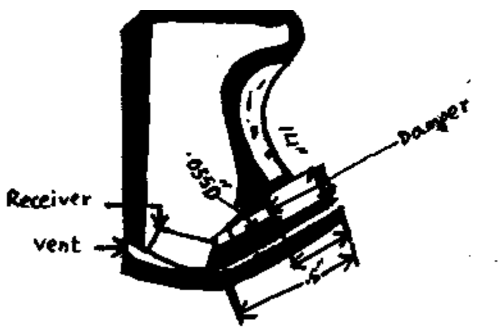


Fig.9: Canal lock mold.

II. All-in-the earmold(Modular hearing aid model):

This mold is designed to hold and couple an All-in-the-ear instrument to the ear. The custom ITE aids are determined on a prescriptive basis by the manufacturer from audiometric information. Control of characteristics through earmold modification is limited. Venting adjustments can be made in some cases. Owing to the limited space available, the tube system from the receiver to the eartip is necessarily short. Tubing diameters on the order of 1.35mm and lengths on the order of 12 mm have been used. The first peak in the response curve is usually at about 2KHz.



Perves (1980) described a dual tubing or stepped bore arrangement for ITE aids that substantially increases the high frequency response. This is depicted in Fig.10. The first section of the stepped bore at the receiver end, is 1*4 mm in diameter by 6.4 mm long and increases to 3.6 mm in diameter by 6.4mm long for the second section. At the junction of the two bores, a 2200 CGS acoustic ohm fused mesh damper is placed to smooth the response. For short earmold shells, the large portion of the bore is extended beyond the eartip to maintain the quarter wave resonant increase in response.

Killion and Murphy (1982) described a removable damper construction for TTE aids that permits the use of dampers of different resistances and also allows for cleaning or replacement of a damper clogged by earwax. The construction is such as to minimize collection of earwax on the damper itself. Knowles type BF dampers are used.

III. Non-occluding options:

The non-occluding or open earmolds were used originally with CROS (Contralateral Routing of signals) hearing aids (Harford and Barry, 1965). The separation provided by having the microphone on one side of the head and the receiver feeding into the open ear canal on the other side permitted a fair amount of gain to be used without feedback. The use of non-occluding earmolds on the same side as the microphone is also very successful where low to moderate gain is adequate. This arrangement is referred to as IROS (Ipsilateral Routing of signals); used for mild gain (approximately 30-36 dB), low MP0(and little or no gain below 750 Hz) instruments. The original purpose of the non-occluding mold was to allow unamplified sound to enter the unilateral's normal ear. However, the additional dividends; open or 'no-mold' fittings as listed by Hodgson, 1981 inelude:

(i) Reduction of low frequency amplification and thereby bringing about a reduction in tolerance problems and the effects of upward spread of masking in noisy situations.

(ii) Retention of the useful resonance effects of the ear-canal which are lost when the ear is occluded with a standard mold.

(iii) To facilitate extended high frequency amplification.

Construction: The figures below illustrate the three popular methods of providing open canal coupling of the aid to the ear.

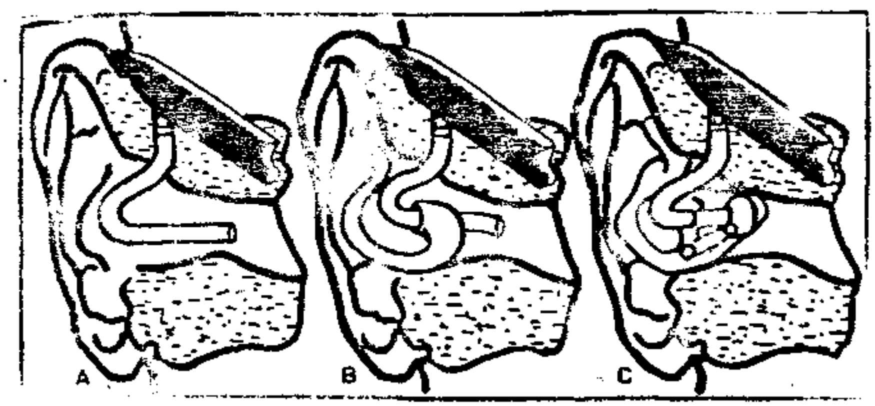


Fig.ll:Three popular methods of providing open canal coupling of the aid to the ear.

The non-occluding earmold consists of a piece of tubing projecting into the earcanal. A skeletonized earmold designed to hold the tube in place with minimal blocking of the earcanal is the preferred arrangement (Lybarger, 1985, cited by Katz,1985). The importance of not reducing the size of the canal opening by an earmold to avoid loss of high frequency response is pointed out by Hewitt (1977). If no mold is employed, a heavier wall tubing is ordinarly used to give the necessary mechanical strength. In brief, the three methods includs -

(i) a length of tubing projecting into earcanal,

(ii) or a skeleton mold to hold the tubing in place without blocking the ear canal,

(iii) where greater retention of hearing aid is required, open bore, short canal, enlarged vented coupler is utilized.

These are CROS, A, B and C varieties. The other non-occluding earmold options include:

* Janssen
* Free field
* Modified free field
* The dual diameter nonoccluding earmold
* Advanced design free field or Universal non-occluding molds.

Janssen earmold: In this type of open earmold, the canal portion of the mold is fabricates at the top of the eareanal and the bridge portion of the mold totally eliminated. This brings about a more efficient non-occluding

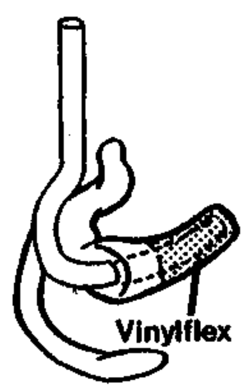
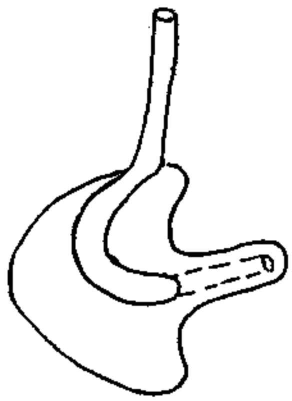


FIG. 12. JANSSEN MOLD.

effect i.e. the low frequency sound pressure reduction. To lower the incidence of acoustic feedback, Janssen molds provide a long canal.

Modified free field mold:- This office adaptation requires the dispenser to take a laboratory-fabricated non-occluding earmold and fill in the concha but not the canal with an acrylic plate. The plate is then drilled away with a burr at the helix. The amount drilled away is determined by the amount of feedback once the client sets the volume to his comfortable listening levels with the aid.



Fia.13:Modified free field mold.

Dual diameter mold: (Proposed by Lybarger, 1985): Fig.14 represents the dual diameter mold; useful for clients with audiogram configuration presenting normal or very near normal hearing oat to 1500-2000 Hz and then a steep drop in threshold. Lybarger's unservation was that a

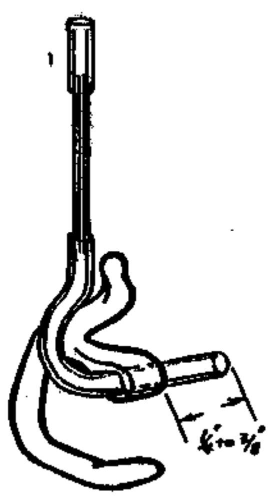


Fig.14: Dual diameter mold

reverse horn effect by reducing tubing diameter to 1/32" from the standard # tubing normally used, and then to go back to # 13 tubing size in the canal, would be acoustically desirable since the reverse horn effect would attenuate below 1500 Hz.

Advanced design free field or Universal non-occluding molds:

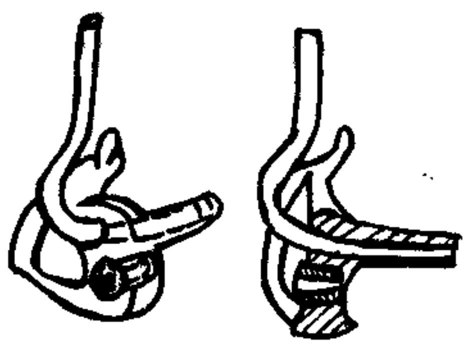


Fig.15: Advanced design free field mold.

This mold, illustrated in Fig.15 is required for those clients where the degree of loss indicates that a non-occluded mold will probably not occlude the earcanal opening sufficiently to provide useful gain before onset of acoustic feedback. This mold follows the design of older CROS mold styles but expands the bridge area and installs in a S.A.V (Select-A-Vent) plug that provides the dispenser with variable venting control over the amount of increased occlusion that this non-occluding style offers. This is useful for patients with chronic suppurative otitis media where full occlusion presents a medical hazard.

"Of the many commonly so-called 'CROS' earmold styles, these would best be consolidated into two styles— the Janssen mold and the Universal non-occluded mold" - Mynders, 1981.

This offers the dispenser and his clients the full range of benefits from non-occluded earmold styles.

Studies reflecting the affects of non-occluding earmolds:-

Effects of earmold on the performance characteristics can be investigated by one of the following ways:

i) Probe tube microphone measures.

ii) Speech reception and speech discrimination data.

iii) Real ear measurements on KEMAR (Burnett, 1981) highlighting the effects of the head, concha and tar canal (external ear affects) and those due to acoustic feedback that can result in sharp peaks in response. Also any phase cancellation or addition between direct and amplified sound is seen.

iv) Using earsimulator, an earcanal extension and a concha simulator (Lybarger, 1980), which gives results close to those obtained on KEMAR with the exception of feedback and phase cancellation effects.

Feeding the signal from the hearing aid into an open air causes loss of low frequency amplification relative to the performance of the aid with a standard earmold. (Harford and Dodds, 1965). Larger the vent size, greater is the low frequency attenuation. Lybarger (1967) estimated that amplification below l000Hz is almost eliminated. Earcanal resonance is retained. The difference, for the frontally incident sound is as much as 16-17 dB at 2.7 KHz (Kuhn 1980).

Regardless of alteration in the frequency response with the unoccluded molds, studies indicate that there exist only minor differences between the aided thresholds obtained from subjects with standard and open earmolds. Dodds and Harford (1968) and Hodgson and Murdock (1970) reported speech thresholds about 3 dB poorer with open earmolds for subjects whose high frequency loss had an average slope of about 20 dB per octave across the speech range. Jetty and Rintelmann (1970) reported the following differences -

i) For subjects with flat conductive loss, the average speech threshold was 1.7 dB poorer with the use of open earmolds.

ii) However, for subjects with sharply sloping sensorineural loss (25 dB per octave across speech range), the average threshold was 2.0 dB better than with the open mold.

iii) For subjects with gradually sloping sensorineural loss (about 7 dB per octave),thresholds obtained with the use of standard molds averaged 2 dB better.

Frank and Karlovich (1973) in a study on 10 otologieally normal subjects (with hearing loss 10 dB at 0.25 to 8KHz) with CROS aid coupled to custom-made standard earmold and open mold reported no variation in speech reception threshold with earmold type. These highlight that the deterioration in aided SRT resulting from the use of an open earmold does not pose significant problem.

"The greatest dividend obtained from the open earmolds is the enhancement of auditory discrimination ability"

Table-1: Summary of discrimination scores data utilizing a CROS hearing aid with open and standard earmold.

Sl. Researchers	Presentation level dBSPL/ dBSRT	Open Mold	Standard Mold	Improvement
l.Dodds & Harford 1968.	70 dBSPL	81.4	71.4	10
2.Jetty and Rintelmann,1970	26 SRT	87	76.8	10.2
3.Hodgson and Mardock,1970	70 dBSPL			
In qaiet		84.6	79.3	5.3
In noise		62.7	52.8	9.9
4.Frank & Karlovieh 1973				
Low pass 400	16 SRT	39.0	32.2	6.9
	32 SRT	59.0	48.8	10.2
Low pass 700	16 SRT	45.6	37.4	8.2
	32 SRT	70.2	63.0	7.2

(Hodgson, 1981). Several studies have compared the unaided vessus aided disrimination scores with the use of standard and open earmolds (Lybarger, 1967, 1968; Dodds and Harford, 1968; Green and Ross, 1968; Green, 1969; Harford, 1969; Dunlavy, 1970; Hedgson and Murdock, 1970; Jetty and Rintelmann 1970; Frank and Karlovich, 1979? Lund and Hoyvik, 1979; Sung and sung, 1982).

In general, subjects with high frequency loss performed better with open earmolds than with standard mold or when unaided. Subjects with flat loss performed about the same for all three conditions. Superiority of the open mold for subjects with high frequency loss is related presumably to two conditions:

i) The open mold affords more comfortable listening to those with high frequency loss owing to its low frequency attenuation. The subjects, hence can increase the gain of the hearing aid and obtain greater amplification of high frequency signals where the need is greatest without any discomfort.

ii) Unaided audition of low frequency signals and ear canal resonance mediated by the unoccluded earcanal result in better fidelity and greater intelligibility.

Epitomizing, Lybarger, 1968 quotes "With the open canal arrangement, both the gain and saturation output are cut by the acoustical systems of the ear and even very loud sounds in the low frequencies would not produce an uncomfortable level through the hearing aid as would be the ease with closed mold".

Another angle of viewing the performance of open mold is in relation to its reduction of upward spread of masking. Frank and Karlovich (1973) speculated that open earmold advantage for discrimination scores is probably due to sensitivity difference between the low and high frequencies. This sensitivity differences may interfere with discrimination as a result of simultaneous masking of the low frequency vowels formants and/or to the involvement of temporal masking of amplified low frequency (vowel) components of the test word upon the relatively higher frequency (consonant) component.

Danaher and Coworkers (1973) related the upward spread of masking to decreased intelligibility in patients with sensorineural loss. They found that when normals and sensorineurals listened to vowels shaped so that only second formant energy was present, both groups performed about the same. However, with a broader spectrum signal containing both first and second-formant energy, the sensorineurals did much poorer than the normals. The investigators recommended that, in individual hearing aid selection, attention might be given to some reduction of amplification in the frequency region where F_1 falls, which is variously between 250-1000 Hz.

That the subjects with high frequency loss prefer open to standard molds has been widely reported. In a survey by Dodds and Harford (1970), it was found that among patients with high frequency loss, those who used open earmolds were more likely to wear their aids full time than those with standard molds. Of 18 subjects evaluated by Hodgson and Murdock (1970) in a study using open and standard melds, 12 preferred the open and none preferred the standard mold. These subjects with high frequency loss indicated that speech was more comfortable, clearer or more natural when using the open mold. Bresson (1971) reported that 200 patients (presbyacutics and noise induced hearing loss) nearly unanimously stated that their situation had improved when they changed from standard to open molds. Land and Hoyvik (1979) evaluated 33 patients with acoustic trauma fitted with binaural eyeglass aids. With free plastic tube in the earcanal. In both these studies, patients reported of benefits being obtained with the aid at conferences/meetings/ social occasions - that they "could hear and understand better.... became leas tired than previously, and were less troubled with canal humidity and irritation".

Concluding, these non-occluding molds, forming one of the major options in the consolidated earmold option list may be used with the unilaterals in the CROS settings and the IROS mode. This permits the possibility of true binaural fitting for those with marked high frequency hearing loss. This also permits binaural hearing in unilateral hearing impaired patients who require non-occluding molds for medical reasons.

IV. Anti feedback molds:

Acoustic feedback is, by definition, the return of some of the energy of the output signal from a hearing aid receiver to the input transducer (the microphone). - Denziz Brook, 1984.

Table-2: Electrical analogy of acoustic feedback assuming positive feedback modality cited by Nolan and Tucker (1985).

OUTPUT = INPUT x GAIN (VOLTS)

let INPUT = 1 VOLT

GAIN = A.

Assume a fraction B of the output returns to input and adds to input (+ve feedback)

Feedback = AB.

To maintain output at a constant level, one would have to reduce input

INPUT = 1-AB.

Gain $A^{1} = \frac{A}{1-AB}$ $\frac{\text{Output}}{\text{Input}}$ (Volts)

as AB --> 1

1- AB -> 0

.*. $A^{1} \rightarrow \alpha$

i.e. no input is required for a continuous saturation output— oscillation feedback howl results.

The result of this is a characteristic high pitched whistle when the aid reaches oscillation point and a continuous saturation output is produced. An amplification system in this condition is totally unacceptable because of the gross distortion of any processed signals, high output and the distracting and embarrassing effects on the user. This can be stopped by reducing the gain of the hearing aid with the untoward consequence of an ineffective amplification. Acoustic feedback from unsatisfactory earmolds not only limit the effective use of body-level aids, bat preclude altogether the use of head worn aids (Johansen, 1975; Long, 1976).

The major factors external to the aid contributing to acoustic feedback comprise the following:

1. Sound leakage from an acoustically poor fitting earmold being the most significant factor.
2. Sound leakage resulting from improper insertion into the ear owing to disorientation of the landmarks.
3. Sound leakage from the coupling point between earphone receiver and lockspring for the body worn aids.
4. Sound radiating from the sound tube in post-auricular aids.
5. Sound radiating from the tube connections, earhook-receiver nozzle coupling point and other plumbing in post-auricular aids.
6. Sound radiating from the ear as a result of an increase in sound pressure level in the ear canal, because of a temporary conductive disorder or hard impacted wax. This increase in SPL results from a reduction in compliance of tympanic membrane, and in certain cases, an increase in user gain control setting.

In the feedback management programme, some of the following techniques can be employed including appropriate techniques of impression taking, and in-office modifications like oiling the ear and reducing the vent size as adopted by Orton, 1981, or fabricating a new earmold. Others, as recommended by Brook,

(1984) include:

1. Parents (in the case of young children) ought to be trained on insertion, removal and day-to-day care of earmolds. Particular attention should be paid to the need for good after-care of earmold plumbing in post-auricular instruments - spare lengths of tubing being provided.
2. Thick-walled tubing should be employed with high gain post-auricular aids.
3. In the case of body worn aids - earmolds should be carefully examined to ensure that the look ring is correctly seated and the backplate is flat prior to fitting. Sub-miniature earphone receivers should be employed. The plastic washer on the back of the receiver should be replaced by a layer of plasticine or 'blue tac'. Attention must be paid to the condition of the receiver nub, which can, over a period of time, be worn out. Use of nylon lock springs as standard will overcome this problem.
4. Contralateral routing of signals with twin body worn aids is not a method to employ in trying to overcome the feedback problem.
5. Arrangements must be made for an examination of the ear-canal and impedance bridge measurements in cases where feedback presents a persistent problem or occurs suddenly for no apparent reason.

Applying the above guidelines if the feedback problem continues to persist, the use of antifeedback molds becomes imperative. The options under this category include:

1. Power mold.
2. Tragus mold.
3. Macrae anti-feedback mold.
4. Receiver in the earmold.
5. Macrae's high cut cavity vent.
6. Composite earmold.

1. Power mold: One of the causes for acoustical feedback is the dislocation of the mold during mandibalar movement. This antifeed back mold tackles the problem of breaking the acoustic seal by reducing the canal portion so as to not contact the lower canal wall. The seal of this mold is at the concha and entrance of external auditory canal (Fig.16).

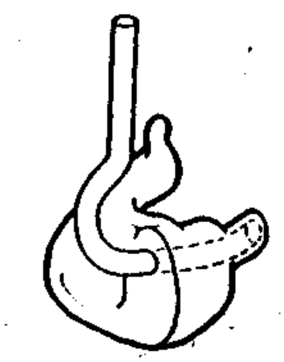


Fig.16: Power mold.

2. Tragus mold: The standard earphone-coupled mold (receiver mold) can be modified as the tragus mold with built up bowl and material expanded to cover the tragus and to reduce feedback for use with high gain aids.

3. **Macrae anti-feedback mold**: When use of BTE is precluded owing to the occurrence of acoustic feedback, this resonator type of earmold is useful. The mold employs a very large cavity, two tubes in the cavity, an acoustic danger and a pinhole vent in the helix area. This permits the fitting of a BTE aid,68 dB full-on-gain and 136 dB HF average $SSPL_{90}$ at full volume control setting without feedback (Mynders, 1986). The mold is illustrated in Fig.17.

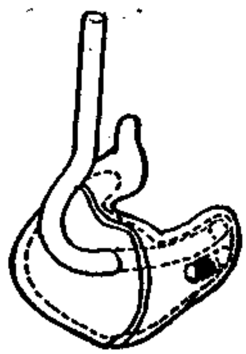


Fig.l7:Macrae anti-feedback mold

4. **Receiver in the earmold**: Ross and Cirmo, 1980; apart from the above mentioned causes for acoustic feedback, report that mechanical feedback can occur because post-auricular hearing aid and receiver are encased inthe same frame. Boor and/or inadequate mounting and isolation of one from the other allows transmission of vibrations developed in the receiver to the microphone, particularly at high gain and output levels.

Also, electrical feedback can be caused in some ear-level aids by inductive coupling between the magnetic coils in the receiver and the microphone. To account for these problems, by embedding the receiver in an earmold, it is possible to minimize feedback inan ear-level hearing aid, permitting the user to take advantage of their fall performance characteristics.

Construction: Receiver of the ear level aid is removed from the case and connected to the amplifier output by an electrical cord. A plug is removed from the instant mold and receiver placed in the mold, ensuring that the sound outlet from the receiver is proximal to the earmold orifice. The plug is then placed in the instant mold and sealed with additional impression material. The electrical cord between the amplifier in the hearing aid and now external receiver is run through the tone hook into the earmold.

In the maximum rotation of gain control setting in the modified condition, no feedback was found to occur and the average gain and output differences between the two conditions varied between 7 and 13 dB.

5. Macrae's high cut cavity vent: Macrae (1981, 1983) developed a vent for high powered aids that significantly reduces the amount of high frequency sound that escapes through the vent to cause acoustic feedback. In this arrangement,the main vent feeds into a cavity In the body of the earmold, from which a small hole

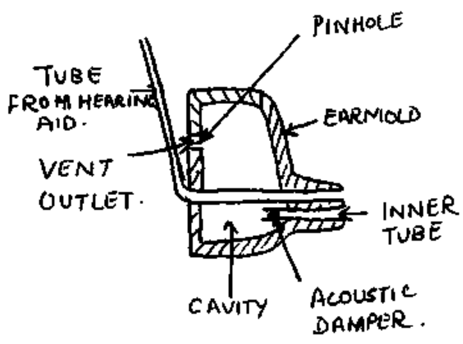


Fig.18:Macrae's high cut cavity vent

leadS to thE outside air. A low-pase filter is thus formed that allows normal venting action for low frequencies, but blocks the transmission of feedbackk causing high frequencies to tha outside. This mold is depicted in the Fig.18. A reduction on the order of 20 dB in radiated high frequency sound from the vented earmold can be achieved.

The composite mold- This mold is dealt within Chapter-4.

IV. Acoustical style options are discussed ia Chapter-4.

Earmold modifications for the difficult-to-fit.

1. Earmold for geriatrics:

"Hearing aid fitting is often difficult and frequently less than satisfactory". (Willeford, 1971). Among other problems, lack of finger dexterity due to arthritis etc. prevent the geriatric patients from carrying out simple hearing aid management tasks like inserting the battery, making volume adjustments, cleaning and inserting the earmold. Pertinent to earmold insertion, the two commonly encountered problems include:

i) Keeping the finger out of the way when inserting the mold,

ii) Remembering which end of the earmold goes into the ear (Navarro, 1976).

When use of eartips is not feasible, use of the following earmold modification helps. This is fabricated from an instant mold material with a handle protruding from the concha but care being taken not to extend this beyond the lateral margin of the pinna and not to interfere with placement of the tubing. The mold is represented in Fig.19.

Fig.19 Earmold for geriatric.

Typical physical dimensions of the handle are approximately 1 cm wide by 5 cm high with slight concavity to allow firmer grip.

In short, the above earmold innovation can be applied to the geriatric hearing impaired population with digital dexterity and severe visual problems precluding the use of conventional aarmold. This design is recommended for All-in-the-ear mold, the receiver of the body-level aid precluding its usage.

2. Expan earmold: (BENTZEN, 1972)

This earmold is a mass produced, individually adjustable earmold of soft, nontoxic material which can be fitted without impression; first developed by Daves, Moller and Stennevad. The mold can be employed with all types of hearing aids where an earphone is built into the hearing aid itself. The requirements for this type of earmold include -

i) anatomical correctness.

il) ability to be used for both right and left ear by adjustment of a nut onthe outside,

iii) ease of operation

iv) made of soft material which is non-irritant to the skin in the earcanal.

v) must be cosmetically satisfactory.

Principle of construction is described by T.E. Nielsen Hearing Dealer, August, 1971:

The expan mold consists of a hollow and soft flexible bulb of clear aon-toxic plastics which is contoured to fit the basic shape of normal ear canals. Attached to the tip of the flexible bulb, a hollow plastic bolt goes right through inside and comes out at the opposite collar-shaped end of the bulb. An angle-shaped nut is zcrewed on the bolt at the collar shaped end (all three parts are transparent). The sound tubing is attached on the angle nut. By turning this clockwise, it presses against the soft plastic bulb, thus compressing it with outward expansion as the logical consequence. This system gives continuous size adjustment within the size limits set by the total size of the bulb.

Expan in five different sizes are available, each mold being continuously adjustable from the largest setting of the previous size, to the smallest setting of the next and thus covering all diameters of ear canal from 4 to 12 mm.

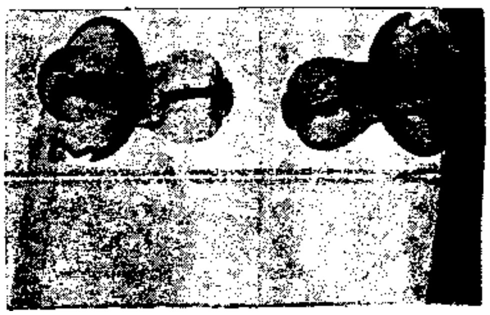


Fig.20* expan earmold

The non-toxic PVS material utilized for its manufacture ensures its use for patients allergic to traditional earmolds. This can also be utilized with body-worn aids if the earphone is clipped onto a hairslide from where the sound is led through tubing to an expan earmold. This can be of special importance for patients who must sleep with their aids, on account of tinnitus

However, this is not a universal solution owing to the following acoustic and anatomical factors -

i) It cannot be used if the earcanal is less than 4 mm or more than 12 mm.

ii) It cannot be used if the ear cartilage is too stiff.

iii) It is contraindicated if the auditory loss measured by SRT is over 40 dB.

Table-3: Indication for use of 4 types of earmolds in relation to diameter of the earcanal.

Type of meld	Diameter of ear		Type of: aid		
	under 4 mm	Over 12 mm		tnger	Hearing spectacle
Tube		+	-	(+)	+
Expan			(+)	+	+
Earmold	+	+	+	+	+
Earmold with soft tip	-	+	+	-	

Table-*: Indication for 4 types of earmolds in relation to the amount of auditory loss, measured with SRT.

Type of ear-mold	Hearing loss indicated with SRT			Modulation of frequency
	Under 50dB	50-80dB	Over 81dB	
Tube	+		- -	. 4=USABLE
Expan				
Earmold	+	+	-	
Earmold with soft tip				

3. Earmolds take to space with gemini flights:

Astronauts are fitted with eaimolds (fabricated from a derivation of Ethyl-Methacrylate family material) containing a radioreceiver. This material becomes slightly pliable from the warmth of the body, bringing about an airtight aeal.(Fegel, and Reznek, 1966).

4. Swimmer molds:

Swimming is no longer contraindicated for patients with grommet insertion following myringotomy & those with chronic ear disease. The solution lies in fabrication of custom-made earmold without the sound bore of a composite of high viscosity silicone polymer (Insta-mold) the mold being soft, nontoxic nonallergenic and nonshrinkable (Kasden and Robinson, 1974).

CHAPTER-4

ACOUSTIC MODIFICATIONS OF EARMOLDS

Technological advancement in the field of amplification system has seen drastic improvements in responses and sound quality of hearing aids over recent years, and further improvements can still be made by modifying the sound channel from the hearing aid to the tympanic membrane. These techniques involving the principle of acoustics have been known to science for over a century and to the industry for decades, bat have only recently been put to use.

For the researcher and dispenser, as reported by Gerling (1981), the new earmold technology has some basic philosophic considerations. They are -

a. To preserve the balance/coustically between the high frequencies and low frequencies in the normal speech spectrum;
b. To preserve the normal eardrum - free field transfer;
c. To extend the high frequencies in wearable hearing aids;
d. To minimize and/or eliminate the standard peak in hearing aid responses at 1000-1500 Hz for many mild and moderate losses;
e. To gradually slant upwards the frequency response of an aid;
f. To keep the output of an aid within the client's dynamic range.

These are accomplished by adjusting the frequency response of the hearing aid with special attention to the earmold and associated plumbing.) Individual adjustments to low, mid and frequencies with the use of venting damping and horn effects respectively can be made.(Fig.21), Though this ought to be interpreted with CAUTION AS THE EFFECTS ARE NOT AS CLEAR CUT AS IS OFTEN IMPLIED. Furthermore, the material used in fabrication impedes achievement of the required modifications.

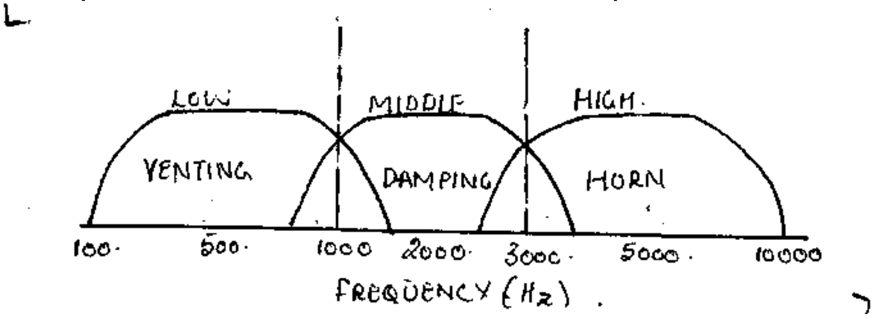


Fig.21: Earmold modifications and frequency of influence.

Measurement techniques:

As reflected in the introduction, tubes, cavities and resistive (damping) elements associated with earmold coupling system bring about a radical change in the signal measured at the output end of the earmold. The resultant effects may differ, depending on the measurement procedure adopted. Traditionally, the following measures have been employed including:

i) 2cc coupler measures ii) Zwislocki coupler me[illegible]ures. iii) Probe microphone measures	Leavitt, 1981 cited by H[illegible]gson and Skinner, 1984.
iv) Bone conduction threshold measurements used to assess the reduction of the occlusion effect. v) Sound field threshold measurement to assess the context to which earplug effect has been eliminated	Frank, Cooper, McFall, 1976, Macrae, 1984.

The present section deals with the different modifications employed, their acoustic principle and utilization of the above measurement techniques which bring about the required alt tions in the frequency response of the aid.

The acoustical style options listed by Mynders (1986) include -

1. Parallel vent
2. Diagonal vent
3. External vent
4. SAV
5. PVV
6. Custom vents
7. Short-canal/wide bore
8. Belled bore
9. Dual diameter
10. Advanced design free field mold
11. Killion 6R12
12. Killion 6AM
13. Killion 8CR
14. Killion 6B0
15. Killion 6B5
16. Killion 6B10
17. Zillion 6C5
18. Killion C10
19. Knowles Dampers
20. Killion 6EF
21. Libby Horn 6-EFA
22. Libby Horn 6EFB
23. Libby Horn 8CR
24. Libby Horn free field.
25. C.F.A.= 2
26. C.F.A.=3
27. C.F.A.= 4
28. C.F.A. - MC
29. C.F.A = 5
30. Wide range mold
31. F.G.M.
32. Tubing sizes
33. Tube fittings
34. Macrae molds.

I. Venting:

Earmold venting appears to have been used first by Grossman (1943) in combination with button receiver system as reported by Lybarger (1985). Vent is defined as the opening from the surface of an earmold to its sound input channel, Which is an intentionally produced leak." (Langford, 1975), cited by Pollack (1975).

It can also be defined as "the creation of an acoustic pathway between the receiver/earmold system and the atmosphere" - Grover (1976).

Lybarger (1985) defines earmold venting as "an opening leading from a point at the tip of the earmold (parallel vent) or from a point in the delivery tube ahead of the tip (diagonal vent) to the outside air.

Purpose of venting: Earmold venting serves innumerable Purposes which, as listed by Longford (1975), Grover (1976), Leavitt (1981), Macrae (1983), Lybarger (1985), Nolan and Tucker(1984) include the following:

1. Barometric equalization - Vent intends increasing user's comfort by releasing pressure, bringing about a barometric equalization in the e.a.m. This is effectively accomplished by a small vent of less than 0.031 inches internal diameter (ID) having negligible effect onthe basic frequency response carve. For medium length earmold tip, a parallel vent with a diameter of 0.6 mm (0.025 inch. No.72 drill) is effective. (Lybarger, 1985) cited by Katz, 1985. The vent ought to be straight to facilitate easy cleaning with a wire. It allows the air in the ear canal to remain at the same pressure as the atmospheric air, thus preventing an unpleasant pressure difference in the earcanal with speedy fluctuation in air pressure (eg. when driving up a mountain, diving etc.)

2. It eliminates the blocked-up feeling in the ear.
3. It ventilates the ear canal, alleviating the discomfort of excessive heat and humidity.
4. It reduces the earmold's occlusion of the ear canal, Which makes the bone-conducted low frequenciesof the person's own voice much higher in level in his or her ear canal.
5. It prevents the earmold from acting as an earplug at low frequencies, and allows the very low frequencies of the person's own voice to enter the ear at normal levels.
6. It improves sensitivity (Weatherton and Goetzinger, 1971), and speech quality reception or discrimination in noisy and quiet environment (McClellan, 1967; Hodgson and Mardock, 1970? Revoils,1968; Dodds and Harford, 1968; Northern and Hattler, 1970).
7. It bring about radical modification of frequency response - particularly the low frequency reduction(depending on the degree of loss at low frequencies) in efforts to obtain better speech discrimination in quiet and noisy environment. This is a function of the length and diameter of the vent, whether the vent runs parallel or breaks into the sound tube (diagonal) and the characteristics of the hearing aid.
8. It allows direct occurs to the unamplified.
9. This is indicated for medical reasons.

Thus, for clients with noise-induced hearing loss or other similar high frequency loss, the major function involves the reduction of occlusion and earplug effects and mofication of aid's low frequency response.

In clients with severe to profound hearing loss, employing high-powered hearing aids, the most important functions are static pressure equalization and ventilation of the ear-Canal achieved without acoustic feedback and without a significant reduction in low-frequency response.

Effects of venting:

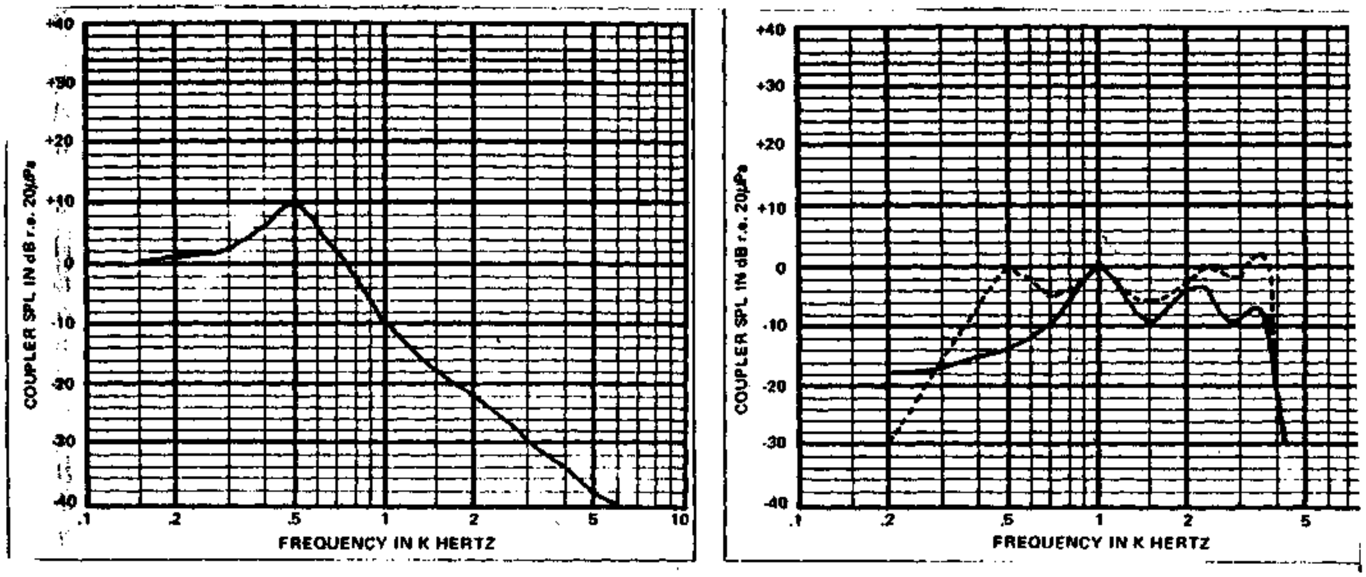
Broadly categorizing, vents may be either fixed or adjustable. Table-5 lists numerous sizes and diameters of vents for different frequency responses. The vent plus the effective volume between the eardrum/tympanic cavity and the inserted mold determine the low pass cut off frequency characteristics of this system.

Table-5: Earmold venting cut off frequency.

1000 Hz	= 0.0875 L	+ 0.0588 D	
	= 0.175 L	+ 0.084 D	
	= ,0.35 L	+ 0.120 D	
	= 0.5 L	+ 0.142 D	
	3 0.7L	+ 0.168 D	
	= 0.L	+ 0.a00 D	
750 Hz	= 0.175	+ 0.063 D	
	= 0.35	+ 0.090 D	
	= 0.5	+ 0.107 D	
	= 0.7	+ 0.120 D	
	= 1	+ 0.150 D	
500 Hz	= 0.175 L	+ 0.042 D	
	= 0.35 L	+ 0.060 D	
	= 0.5 L	+ 0.071 D	
	= 0.7 L	+ 0.085 D	
	= 1 L	+ 0.100 D	
250 Hz	- 0.175 L	+ 0.021 D	
	= 0.35 L	+ 0.030 D	
	= 0.5 L	+ 0.035 D	
	= 0.7 L	+ 0.042 D	
	= 1 L	+ 0.050 D	

L = length (inches)
D = diameter

Fig.22 shows a graph of the frequency response of the earmold for a 500Hz vent when sound enters through the vent channel without any contribution by the hearing aid.



The effective tympanic cavity volume cannot be altered/ however one can alter the physical characteristics of the vent itself by increasing or decreasing the diameter or its length. By decreasing the diameter or increasing its .length, the low pass resonant frequency of the system with decrease. By increasing vent diameter or decreasing its length, the low pass resonant frequency of the system will be increased.

The relationships within this system are:

$$F_o = \frac{1}{2\pi\sqrt{M_A C_A}} \qquad MA = \frac{PoLe}{S} \qquad CA = \frac{V}{P_o C^2}$$

The mass (M) is determined by the length and diameter of the vent, the compliance (C_A) bythe effective volume in associated with the tympanic cavity. Which is the volume existing between the tip of the earmold and the tympanic For measurement, a 2cc coupler is used to represent the tympanic Cavity.

In the above formula,

F_o = resonant frequency
MA = vent mass
CA = equivalent tympanic cavity compliance
Po = Density of air = 0.0012 g/cc.
le = the effective length of the vent = L+1.6 S/cm^2
S = $\pi R^2/cm^2$
Rs = Radiation resistance
V = volume/cc
C = Speed of sound in cm = 34359 cm/sec.

a. <u>Venting for low frequency enhancement:</u>

The inertance of the vent hole, and the equivalent volume in the ear canal form a parallel resonant system. If the acoustic resistance of the vent hole is small compared/to its inertance, the impedance of the vented earcanal can be greater than that of the earcanal alone. When this occurs, the SPL in the eareanal can be higherat the vent resonant frequency than with no vent present. The resultant enhancement is depicted in table through . It can be noted that for lmm diameter vents, there is hardly any drop in low frequency response except for the short hollowed mold, but that considerable enhancement occurs. The frequency of maximum enhancement decreases as the vent length increases. Possibly the most useful low frequency enhancement occurs for the 2mm diameter vents regardless of the tip length. Although the low frequency response is cut, there is a significant increase around 500 to 600 Hz for short and medium tips that will generally make the hearing aid sound louder.

b. <u>Venting for moderate low frequency reduction:</u>

Venting as in the above case (2mm diameter) bring about the considerable low frequency reduction below 350 to 500Hz.

depending on the tip length. Undesirable amplification at medium low frequency may also occur. The amplification may be nearly eliminated without losing the low frequency reduction desired by placing a small amount of acoustic damping over the vent. The 'Modifier' earmold utilizes the principle of a damped vent.

c. Venting for strong low frequency reduction:

For this, a short vent, large diameter must be used. A short-hollowed tip with a 3 mm vent hole is the preferred type. To obtain more low frequency cut with standard type of earmold, vents larger than 3 mm diameter or shorter than 6.3mm length can be used. For even greater low frequency reduction by venting, the open earmold system is required.

Non-adjustable vents: Of the intentional vents, different classifications have been cited in literature.

I. Sullivan's venting classification chart:

		125	250	500	750	100G	1500	2000
Class I vent	0.032 - 0.064	71/2	2					
Claas II vent	0.078 - 0.125	18	15	10	2			
Class III	No canal	18	15	15	9			
introduction No canal to CROS	No Canal 0.200 Hole	30	29	27	22	18	5	
Class IV	Hifi	31	34	30	26	23	13	7
non-occluded	Localizer	33	38	33	33	22	19	12
No mold 1/4	into canal	32	34	35	23	16	15	8
tubing only	Concha only	44	51	57	50	40	26	27

Frequency in Hertz.

II. Macrae (1983) reports of the following three types of vents for use with high powered hearing aids:

i. The capillary vent (Lybarger, 1980) which consists of a constant inner diameter !ID! of about 0.5 mm;

ii. The damped ordinary vent (George, Barr-Hamilton, 1978) consisting of a constant ID of about 2mm and containing an acoustic damper with a resistance of about 2000 acoustic ohms; and

iii. Damped cavity vent (Macrae, 1983) which consists of an inner tube-containing an acoustic damper with a resistance of 2200 ohms - running from the tip of the earmold to a cavity formed within the mold, followed by an outer tube, consisting of a pinhole, that runs fromthe cavity to the outer surface of the mold (Fig.23).

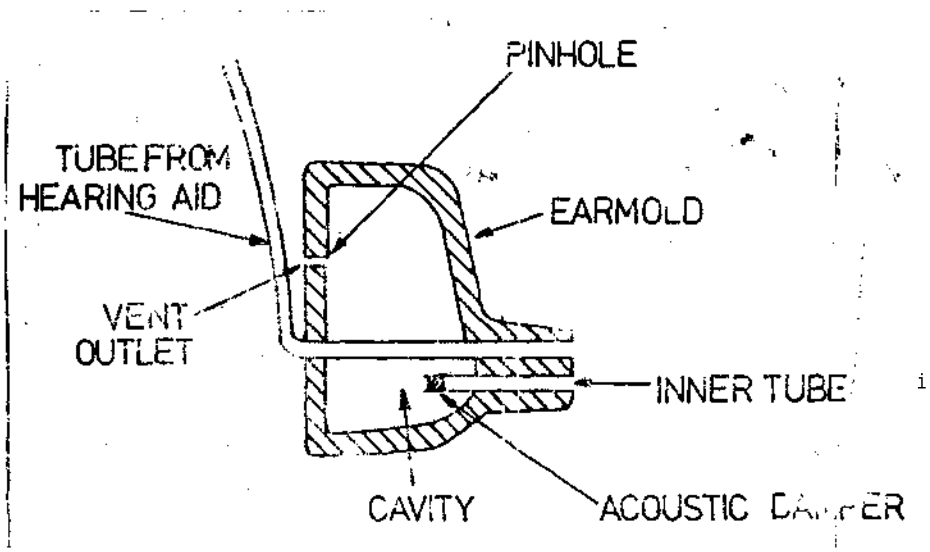


Fig.23 - Damped vent cavity.

To achieve the required acoustic inertance and acoustic resistance the vent/tube size should confirm to the following: (Macrae, 1983).

Table-7: Vent/tube size required to achieve the necessary acoustic resistance and inertance.

Structure	Length	Internal diameter	Additional
Tubing	1.5 cm	1.35 mm (- 16 tubing)	
Outer tube			
i)Pinhole	0.2 mm or 0.25 mm	0.36 mm 0.4 mm	Preferred volume of the cavity = 2.1 cc, but volumes down to 1.4 cc are satisfactory; easy to obtain in adult molds.
or			
ii)Tubing	0.59 cm	1.93 mm (= 13 tubing)	Due acoustic damper with resistance of 100 acoustic ohms (not easily available)

Acoustic damper with a resistance of 2200 okas mast be introduced into the inner tabe of the vent. If it is introduced into the outer tabe, the inner tube and cavity act as a Helmholtz resonator, producing an undesirable dip centered on about 400 Hz in the response of the hearing aid. If pinhole outer tabe is used, it should have an acoustic damper of 100 acoustic ohms, or else the outer tabe and cavity, acting as a Helmholtz resonator, cause a large undesirable peak centered on approximately 800 Hz in the SPL at the vent outlet.

Comparison of the 3 types of vents was done, with resalts depicted in figures 24.

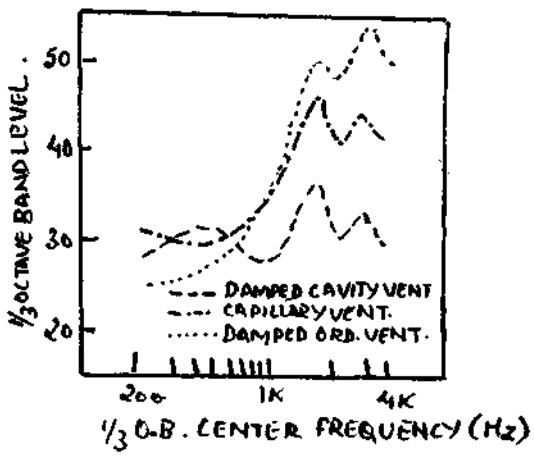


FIG. 24. COMPARISON OF 3 TYPES OF VENTS.

This indicates that all three vents prevent a significant redaction in responses at the low frequencies. They also suggest

i) that the damped cavity vent is the most effective of the 3 at preventing acoustic feedback.

ii) that the capillary vent is the next most effective, and

iii) that the damped ordinary vent is the least effective. However, Macrae (1983) reports that further investigation is required to adequately assess the relative effectiveness of the 3 types of vents and to define the range of hearing aid powers over which each is effective.

III. Side branch (diagonal), parallel vents and external vents:

General consideration: When the vent length is held constant, an increase from small ID to large ID will result in the vent-related resonance increasing in frequency; i.e. the larger the ID of the vent, the higher the frequency of the vent-related resonance. An increase in ID will improve the effectiveness of the low-frequency roll-off below the vent-related resonance, i.e. the slope of the roll-off will become steeper. Conversely, the smaller the vent ID, the lower the vent related resonance and lesser the low frequency roll-off.

Parallel vent/lateral bass tube: This is the preferred type of venting, wherein no intersection exists between the sound bore and the vent resulting in a vent that is as long as the sound bowe. Thus, the impedance of the parallel vent due to mass is large which essentially eliminates the escape of high frequency energy out of the vent. Very small, parallel air release vent in the earmold, of the order of 0.030" or smaller will not cause appreciable change in the hearing aid response except at quite low frequencies (Eybarger, 1967). But as the vent size becomes larger, systematic changes can be observed. Vent associated resonance occurs at frequencies which are related to length and diameter of vent, in conjunction with the size of the earcanal eardrum cavity to which the earmold is coupled (McDonald and Studebaker, 1970). studebaker and Cox (1977) have shown that this vent associated resonance in a tightly sealed earmold can be as much as 8-10 dB at the resonant frequency in the real ear.

When a vent is drilled parallel to the bore of the earmold, that portion of the frequency response below the vent-associated resonance falls off precipitously, but above, the response remains at the same level or increases slightly.

Sidebranch/diagonal vent: The vent intersects the main sound bore of the mold at some point, dividing the sound bore into a portion that is medial and a portion that is lateral to the vent intersection. The theory of side branch vent (Kinsler and Frey, 1961) cited by Studebaker and Zachman (1970) states that when the length of the sidebranch is much smaller than the wavelength of the signal, the side branch may be treated as an orifice. Thus the power-transmission ratio beyond the side branch to that before the side branch may be calculated using the formula -

$$p = \frac{1}{1 + (\pi a^2 / 2Sbk)^2}$$

P_t = power transmission ratio

S = Cross sectional area of the main pipe.

b = length of the side branch including end correction for inertance of air at the orifice.

k - wave length constant - $2/\lambda$ where λ = wavelength

At higher frequencies, the combined impedance of the earcanal/eardrum and the portion of the sound bore medial to the vent intersection is greater than the impedance of the relatively short side-branch vent (Studebaker and Cox, 1977). As a result, high frequency energy can flow through the vent more easily than through the sound bore into the earcanal/eardrum cavity.

The net effect is a redaction in the high frequency output measured at the eardrum. Also, impedance discontinuity at the junction of the vent and the sound bore creates some reflection of acoustic energy, which, however, is minimal in most situations (Studebaker and Cox, 1977).

Small earcanals, at times dictate the use of side-branch vent. Studebaker and Zachman, 1970, Studebaker, and Cox, 1977, Lybarger, 1979, recommended that the side-branch vent be drilled to intersect the sound bore as close as possible to the medial tip of the earmold which will maximize the vent's impedance and ensure a minimum amount of high frequency energy loss. Also, a side branch bass tube has much less feedback attenuation than a bass tube running parallel to the sound canal (Johansen, 1975).

In short, diagonal vents may produce a significant reduction in the high frequency response in addition to the low frequency roll-off. Skinner (1988) reports of upto 10 dB or more decrease in gain above 1000 Hz if vent is large. Parallel vent is preferred owing to its spectral affect being confined to low frequencies. Diagonal vents, however, are often the only available alternative owing to the narrow ear canal. In these cases, the high frequency reduction caused by the diagonal vent may require compensation in both response and gain of the hearing aid. (Ely, 1981). An alternative solution to this, as recommended by British Audiological society (1984) is the use of an external vent as depicted in the figure No.25.

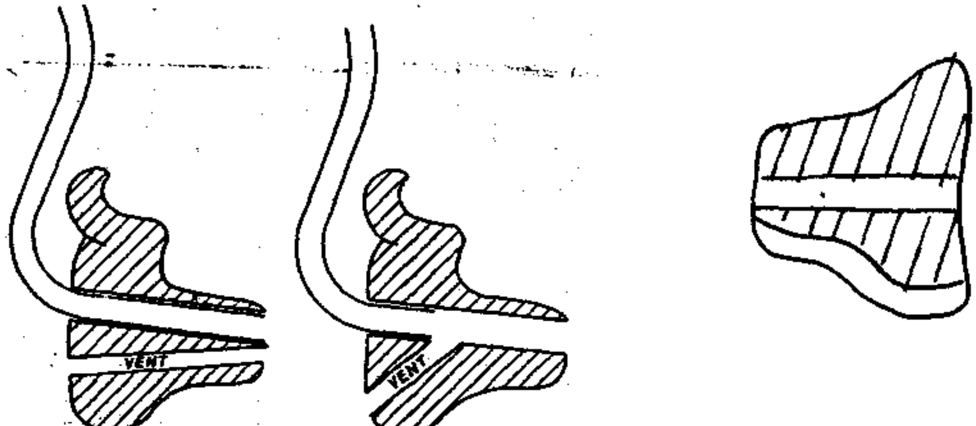
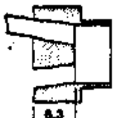
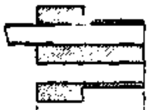
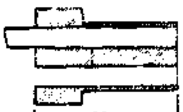
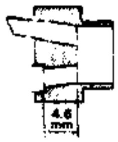


FIG 25. PARALLEL CONFIGURATION SIDE-BRANCH CONFIGURATION EXTERNAL VENT.

Vented Minus Unvented Response in Decibels for Simulated Tubing-Type Earmold on DB100 Coupler (from Lybarger, 1978a).

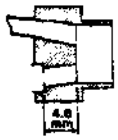
	Vent diameter (mm)	Frequency (Hz) 200	250	315	400	500	630	800	1000	1250	1600
 8.3 mm	*a. Short hollowed tip, parallel vent*										
	1.0	−8	−3	4	8	6	3	1	1	1	0
	2.0	−22	−18	−13	−9	−2	6	5	4	3	2
	3.0	−29	−24	−20	−16	−11	−5	1	1	4	3
 12.2 mm	*b. Short tip, parallel vent*										
	1.0	−2	4	7	5	3	2	−1	1	0	0
	2.0	−17	−13	−3	−2	6	9	3	3	2	1
	3.0	−25	−20	[illegible]	−12	−6	1	4	3	4	3
 16.6 mm	*c. Medium tip, parallel vent*										
	1.0	0	6		4	2	1	1	1	0	0
	2.0	−15	−11	[illegible]	0	9	5	2	3	2	1
	3.0	−23	−19	[illegible]	−10	−4	4	3	3	4	2
 22 mm	*d. Long tip, parallel vent*										
	1.0		6	5	3	2	1	0	0	0	0
	2.0	−14	−10	−4	3	9	5	1	2	1	1
	3.0	[illegible]	−18	−13	−8	−2	6	1	2	3	2

e. "Positive venting valve," short hollowed tip, 1.5-mm diameter parallel vent



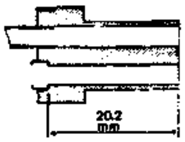
Vent diameter (mm)	200	250	315	400	500	630	800	1000	1250	1600
1 (0.125)	−18	−15	−9	−4	4	9	5	3	2	1
2 (0.094)	−18	−14	−9	−3	4	9	4	3	2	1
3 (0.062)	−18	−13	−8	−3	5	8	4	3	2	1
4 (0.031)	−15	−11	−5	1	8	6	3	2	1	1
5 (0.020)	−9	−5	0	4	5	3	1	1	1	

f. "Positive venting valve," short hollowed tip, 3.0-mm diameter parallel vent



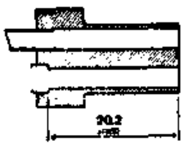
Vent diameter (mm)	200	250	315	400	500	630	800	1000	1250	1600
1	−28	−24	−19	−15	−4	2	1	4	3	2
2	−27	−23	[illegible]	−14	−3	3	2	4	3	2
3	−25	−21	−16	−12	0	4	3	4	3	2
4	−20	−16	−11	−6	6	4	3	2	2	1
5	−11	−8	−3	1	3	2	1	1	1	0

g. "Positive venting valve," long tip, 1.5-mm diameter vent channel



Vent diameter (mm)	200	250	315	400	500	630	800	1000	1250	1600
1	−9	−3	4	9	6	3	1	1	1	1
2	−9	−3	4	9	6	3	1	1	1	1
3	−9	−3	4	9	6	3	1	1	1	1
4	−8	−2	5	9	5	3	1	1	1	1
5	−5	0	5	6	4	2	0	1	1	1

h. "Positive venting valve," long tip, 3.0-mm diameter parallel vent channel

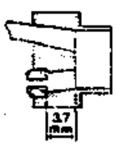


Vent diameter (mm)	200	250	315	400	500	630	800	1000	1250	1600
1	−21	−17	−12	−6	−1	7	1	3	4	3
2	−21	−16	−12	−6	0	7	1	3	4	3
3	−20	−15	−11	−5	1	8	1	3	3	2
4	−17	−14	−8	−1	5	7	1	3	3	2
5	−12	−8	−3	3	4	3	0	2	2	1

i. "Select-a-vent," short hollowed tip, 1.5-mm diameter parallel vent channel

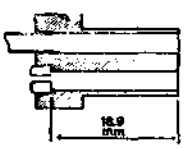
Vent diameter (mm)	200	250	315	400	500	630	800	1000	1250	1600
1 (0.156)	−19	−15	−10	−5	2	8	4	3	2	1
2 (0.125)	−19	−14	−10	−4	3	9	4	3	2	1
3 (0.100)	−18	−14	−9	−3	4	9	4	3	2	1
4 (0.054)	−12	−8	−2	6	9	5	2	2	1	1
5 (0.031)	1	3	3	3	2	1	0	0	0	0

j. "Select-a-vent," short hollowed tip, 3.0-mm diameter parallel vent channel



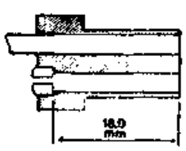
Vent diameter (mm)	200	250	315	400	500	630	800	1000	1250	1600
1	−28	−24	−20	−15	−11	−5	1	1	4	3
2	−26	−22	−18	−13	−8	−2	4	2	4	3
3	−25	−20	−16	−12	−6	0	5	3	4	3
4	−15	−11	−5	1	8	7	3	2	2	1
5	0	3	3	3	2	1	1	0	0	0

k. "Select-a-vent," long tip, 1.5-mm diameter parallel vent channel



Vent diameter (mm)	200	250	315	400	500	630	800	1000	1250	1600
1	−9	−4	3	9	7	3	1	2	1	1
2	−9	−4	3	9	7	3	1	2	1	1
3	−9	−4	4	9	6	3	1	2	1	1
4	−6	−1	7	8	5	2	1	1	1	1
5	1	4	4	3	2	1	0	1	1	0

l. "Select-a-vent," long tip, 3.0-mm diameter parallel vent channel



Vent diameter (mm)	200	250	315	400	500	630	800	1000	1250	1600
1	−21	−17	−12	−7	−1	6	1	3	4	3
2	−20	−16	−11	−6	0	7	2	3	4	3
3	−20	−15	−11	−6	1	8	2	3	3	3
4	−13	−9	−4	3	9	5	1	2	2	2
5	−1	2	4	3	2	1	0	1	1	0

Adjustable venting:

When the hearing aid is fitted, it is at times difficult to pre-establish the amount of venting, if any, that will serve the user.best in his actual environment. Venting systems are now available that permit changes in venting without remaking the earmold. These include -

1. Variable venting value (VVV)
2. Positive venting valve (PVV)
3. Select-a-vent (SAV)

(Blue, 1972; Haigh, 1973; Briskey and Wruk, 1974 reported by Langford, 1985 and Lybarger, 1985).

1. **Variable-venting valve:**

Described by Feiagold (1972), Griffing and Shields (1972), this device is a precision-tooled air valve measuring 0.250" in diameter and 0.156" in depth. It is made from brass and goldplated several times for protection against moisture. The valve is inserted permanently and securely into the earmold to preclude leakage. The value is controlled by a small plastic knob that can readily be adjusted by the user to any degree of open-or-closed valve position. The threaded valve may be turned over 540 of rotation from fully closed to fully open position.

The rationals for using a VVV is that frequency response ia altered by the user and not the dispenser. This permits the user to adjust the venting of his coupler system to improve his hearing in the particular environment (quiet to noisy). The claims made by Grlffing (1971, 1972) for VVV are -

1) The listener has control over the output of his hearing aid over the entire frequency range.

ii) Listener has control over the loudness of the hearing aid output by adjusting the degree of venting.

ill) Listener can enhance has ability to perceive speech in noise by adjusting the degree of venting.

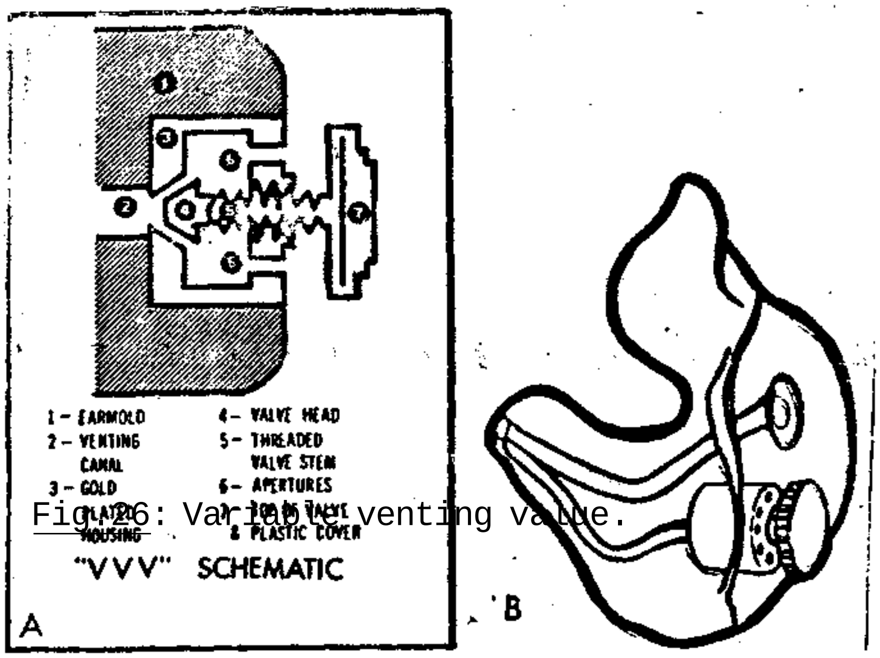


Fig.26: Variable venting value.

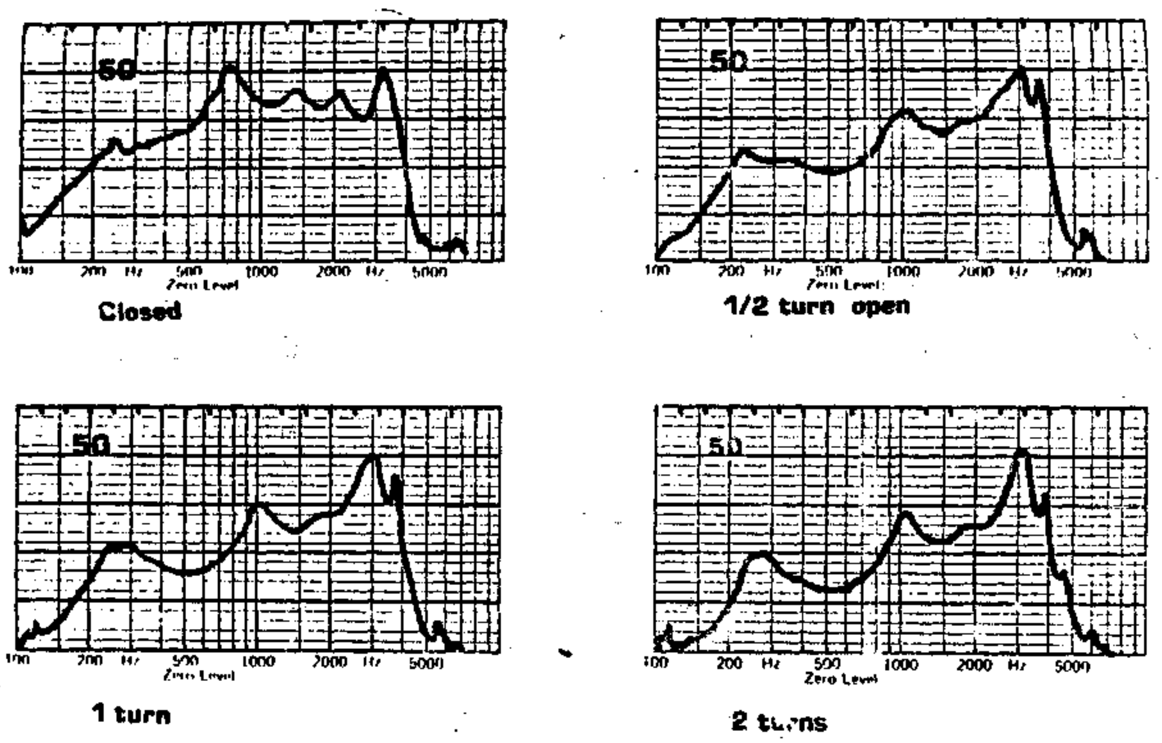


Fig.20: Attenuation charts showing attenuation of hearing aid frequency response with VVV.

The effects of a typical ear-level coupling system, using the VVV as shown in the figure above.From the closed to the full open position there is a considerable reduction in lower frequencies (F_1 and F_2), yet higher frequencies (F_3) have minimal suppression. Lybarger (1978), cited by Leavitt (1981) has indicated that the range of venting with the VVV is similar to that of SAV and PVV inserts described below. Because, some models of the VVV incorporate a highly visible screw on the face of the earmold, the VW may not be desirable if aesthetic considerations are important. Acoustically, however the VVV may provide more venting flexibility since the change in vent diameter can be made more gradually (Leavitt, 1981).

Cooper, Franks and McFall (1975) Investigated the frequency response and loudness reduction characteristics of earmolds with VW, employing both side branch and laterally vented earmolds. Sound pressures were measured at 44 frequencies from 100 to 4,000 Hz. in a modified HA-2 coupler with the VW in for closed, 1/3 open, 2/3 open and 3/3 open. The effect of venting was primarily in the low frequencies. Little or no reduction in intensity was observed in the speech frequency range and a moderate amount was noted in the higher frequencies. The side-branch vented earmolds were found to be more effective than the laterally vented earmolds. Calculated loudness reduction in phons were small. The effectiveness of the VVV, whether assessed by the frequencyresponse or loudness reduction characteristics was found to be achieved within the first one-third of opening. Further opening had little effect. The utility of VW to the geriatric hearing aid user was reported to be questionable.

2. Positive venting valve (PVV):

The PW, as reported by Langford, 1975; Leavitt, 1981; and Lybarger, 1985 is a versatile method for the dispenser and not the user, whereby the degree of venting can be controlled. For the geriatrics and those who have problems with dexterity, it ia the responsibility of the dispenser to determine the vent hole size required to meet the needs of the user. The PW permits the dispenser to quickly and easily bring about increment or decre-

-meat of the vent size. This consists of a permanently installed, clear styrene seating ring and a removable polyethylene venting plug, available in five different sizes, plus a solid plug (as depicted in figure (28).

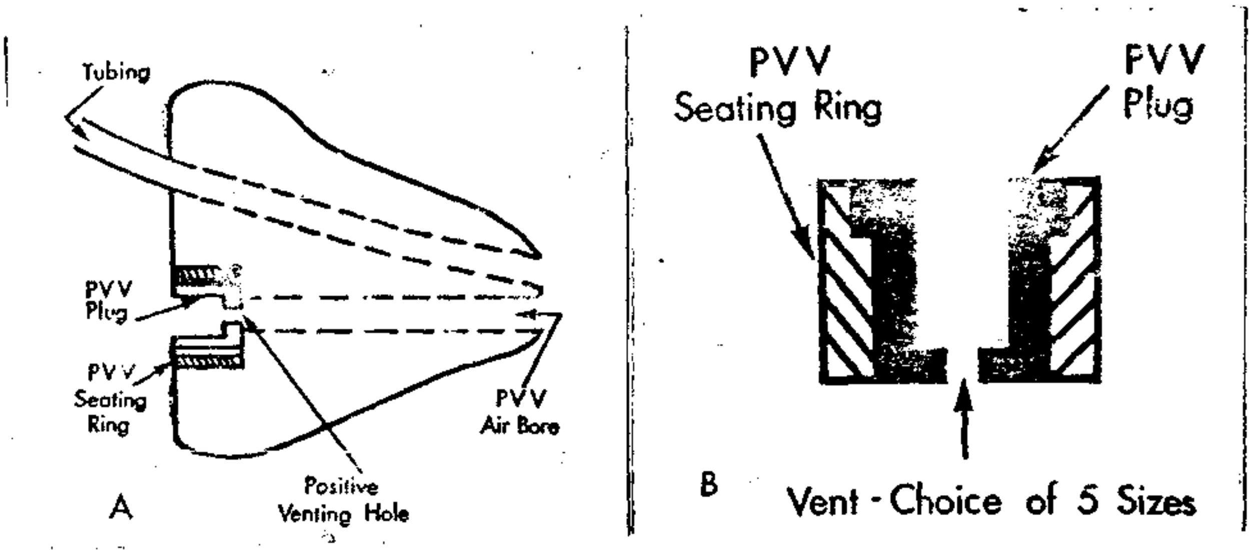


FIG. 28. PVV.

The size of the air bore is 0.155". The size of the plugs range from a large 0.125" to a pinhole size of 0.020", and a solid plug. The earmold laboratories supply the PW in kit foxm, with a tool for easy removal or insertion of the desined plug.

Langford (1975); in a study using standard 2cc coupler determined the effects of vent plugs of different sizes on frequency response when length and ID of tubing were constant.

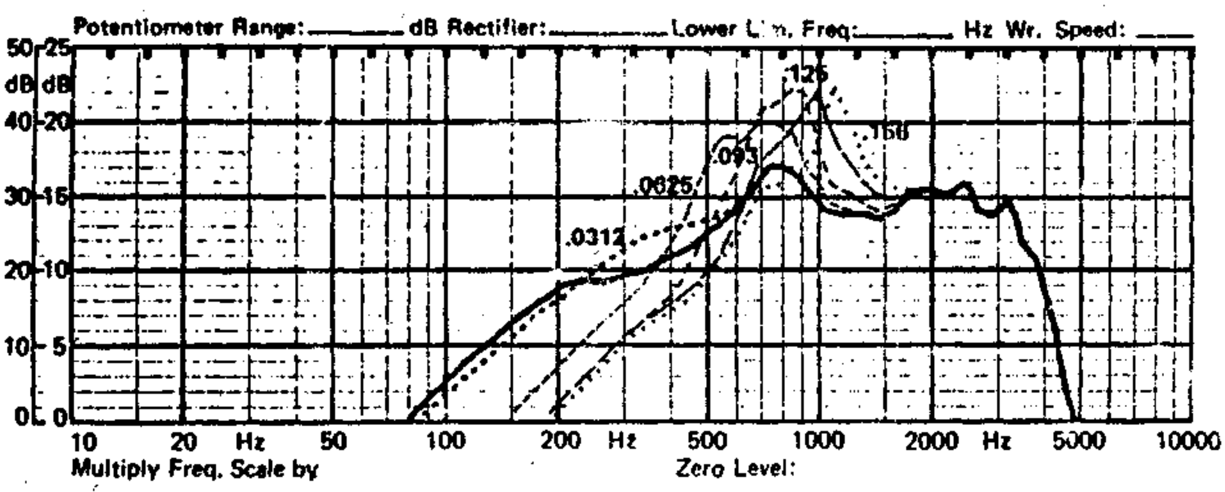


Fig.29; Effects of PW on hearing aid response (Langford,1975)

Results demonstrated that the No.4 and 5 plugs have minimal effects on the frequency response, and are used for pressure relief venting. Use of large vent plugs No.1, 2 and 3 indicates a definite response effect in the first formant (200-1200 Hz) and are used to make the appropriate acoustic modifications so as to fit the hearing aid according to the individual's requirements, similar results were obtained by Lybarger (1985), depicted in table-7. Intermediate vent response characteristics can be obtained by drilling suitable size holes in the undrilled insert or by unlarging a smaller hole to the desired diameter.

3. **Select-A.vent (SAV):**

As reported by Lybarger (1985), this system has inserts with five hole sizes and one without a hole. These include:

Table-8: SAV sizes.

Vent number	Hole size
1	0.156"
2	0.125"
3	0.100"
4	0.054"
5	0.031"

The holes are longer In SAV type when compared to PVV, hence the two types give different amounts of venting for the same diameter holes. "The inserts fit precisely into sockets on the outer face of the earmold. Sound reaches the vent inserts via a sound channel that starts at the earmold tip. If this channel is to long or two small in/diameter, the inserts may have little effect. They work beat when the channel is short and at least 3 mm in diameter"(Lybarger, 1985), this being applicable to PVV also.

Table 8 shows the vent response for SAV inserts when used in a short-hollowed earmold with a 3 mm diameter by 3.7 mm long vent channel. Here again, as in PW, the numbers,l,2, 3 inserts are about the same. The number 5 insert makes a good barometric pressure equalizer with little effect on response. Similar result was demonstrated by Cunningham (1988) in a/study on the effects of SAV diameter change on the insertion gain delivered through a regular earmold with long canal and long parallel vent on 13 otologically and audiologically normal young subjects (5 males and 8 females) With mean age of 24 years. The SAV diameters included, unlike that used by Lybarger (1985) - fully occluded plug, 0.031", 0.062", 0.095", 0.125", 0.1563, and 0.188". Results highlighted that large diameter vents create greater low frequency attenuation when long, large diameter vents are employed.

As in PVV, intermediate vent response characteristics for SAV system can be obtained by drilling suitable size holes in the undrilled inserts or by enlarging a smaller hole to the desired diameter.

II. **Acoustic damping:**

Tubing resonance and a Helmholtz resonance (produced by the acoustic compliance of the air cavity in front of the hearing aid receiver) causes a sharp peak around 1000 Hz in the output of BTE aids as measured in 2ec couplers and around 2000 Hz or higher for ITE aids (Skinner, 1988). These can be excited by sharp transient sounds, causing a 'ringing' or 'echoing' sound. Various acoustic resistance or damping elements have been used to smooth the frequency response of hearing aid - eamaold system, and to control gain and saturation output.

The effect of acoustic dampers on the hearing aid response are determined by:

1. The value of the acoustic resistance, higher values causing more flattening of peaks.
2. The number of dampers used, and
3. The location of damper(s) in the acoustic transmission system (Lybarger, 1985).

Killion (1977), Cox (1979) report that an acoustic damping element ean only dissipate energy when there is air flowing through the element. As the air flow through the element increases, the effectiveness of the damping element increases. Cox (1979) has pointed out that for wave length resonances, the antinodes of the standing waves in a tube represent the positions of maximum air flow, the location of which, for a given frequency and length of tubing can be mathematically calculated. With this, one can being about a selective reduction in resonance peaks at certain frequency by placing the damping elements at the antinode location of unwanted resonant frequencies.

Killion (1977) reported that for the damping to occur, the acoustic damping element should have a characteristic or surge impedance equal to that of the earmold tubing. A damping element that has a resistive value equal to the surge impedance will properly terminate a transmission line (i.e. hearing aid/ earmold tubing) resulting in absorption of all incidental energy, thereby avoiding the reflections of energy which are basically responsible for the resonant peak.

Energy reflected at the point of impedance discontinuity creates standing waves and the consequent wavelength resonances. If the energy is completely absorbed at the end of the tubing line, no reflection and no standing waves occur. Additionally, when the tubing of the amplification system is properly terminated, the transmission of sound down the tube is nearly independent of the length of tubing between the hearing aid receiver and the damping element.

Damping elements - the resistive/damping elements include the following:

i) Lamb's wool

ii) Santered filters (sintered metal pellets)

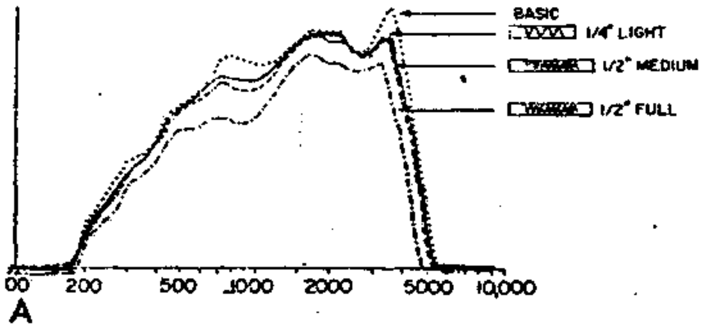
iii) Cotton

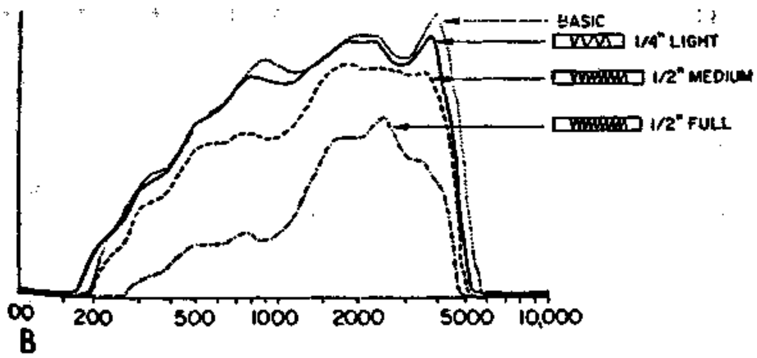
iv) Fused plastic mesh, etc.

Lamb's wool: As reported by Langford (1975), one method of damping is to insert lamb's wool in the tubing or mold of the coupler system. The degree to which the response changes when this is used is difficult to determine unless artificial ear is available, hence changing the response is purely on a trial and error basis, results being obtained subjectively from the user. The density of the packing determines the degree to which the response changes.

Fig.30 depicts that the responses in Fl and F2 can be altered without appreciably affecting F3. Fig.31 illustrates the effectiveness of excessive damping when lamb's wool is used.

Sintered filters: As reported by Decker, 1974; Langford, 1985, an alternate method of controlling the spectrum by mechanical means is to use sintered filters in the tubing. These are small cylinders of stainless steel ball sintered (Welded) toget-her in such a manner that predicts the degrees of acoustic attenuation that can result. They are used to reduce the lower portion of speech apectrum (Fl and F2), with minimal effects on highs (F3). These are considered to have a repeatability of + 1 dB for the same basic frequency response. Fig.32 illustrates the effect of sintered filters on hearing aid response.George and Barr-Hamilton (1978) also report that for earmolds provided with high gain aids, the blocked sensation can be removed without altering the output and occurrence of acoustic feedback using sintered venting.





<u>Fig.30</u>: Lamb'swool - responses in Fl and F2 altered without appreciably effecting F3.

<u>Fig.31</u>: Effect of excessive damping with Lamb's wool.

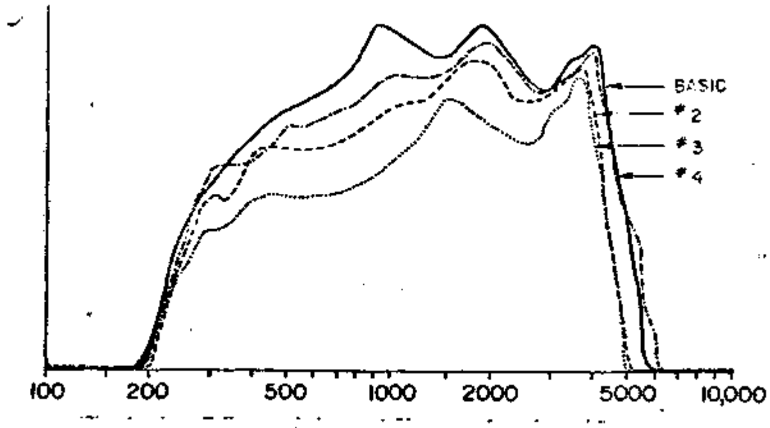


Fig.32: Effects of sintered filters on hearing aid response.

Other dampers: Acoustic dampers have been successfully made from discs with a small hole(s), fine metal screens and porous stainless steel plugs. The type that has found greatest use in recent years (Knowles BF series) is made from very fine fused plastic mesh mounted in a small metal ferrule (ring) which fits into No.13 tubing. Dampers of this type having resistance values of 680, 1000, 1500, 2200, 3300 and 4700 (cgs) acoustic ohms are currently available (Lybarger, 1985).

To obtain optimal response smoothing in a particular frequency region, the dispenser identifies the frequency of the unwanted resonant peak, calculates the surge impedance of the tubing (1400 ohms when No.13 tubing is used), and places the appropriate damping element at the desired antinode location in the tubing.Killion (1977) reports that this process may be simplified by placing two appropriate damping elements 20 and35 mm back from the tip of the earmold. Skinner (1988) reports that some manufacturers use a single 680 or 1500 or 2200 acoustic ohms damper in the earhook rather than near the earcanal because moisture from earcanal can clog the damper and cut off the sound. When the damper is placed at the tip of the earhook, there is little effect on the resonant peak at 2000Hz because of the damper's location at 1/4 wavelength node (Lybarger, 1985).

Other properties:

In addition to smoothing the resonant peaks in the output of the amplification system, which often reduces patient - complaints associated with tolerance problem, this can reduce feedback problems which may be associated with sharp peaks in the output of the system (Killion, 1980).

In a recent study, Cox and Gilmore(1986) found that 8/10 hearing impaired listeners found hearing aids without dampers to produce slightly clearer, more pleasant sounding speech than those with dampers. Though further research is implicated, this suggests that acoustic dampers do not necessarily improve sound quality.

Carlson's Twin Tube Procedure:

Carlson (1974) reported by Levitt(1981), developed a technique effectively eliminating the tubing wavelength resonances utilizing two identical lengths of properly damped tubing in a parallel circuit configuration. One length of tubing ends in a closed plug, which represents a high impedance termination, and the other terminates at the earcanal (a relatively low impedance termination). The figure 33 illustrates this arrangement for eyeglass and ear level aids.

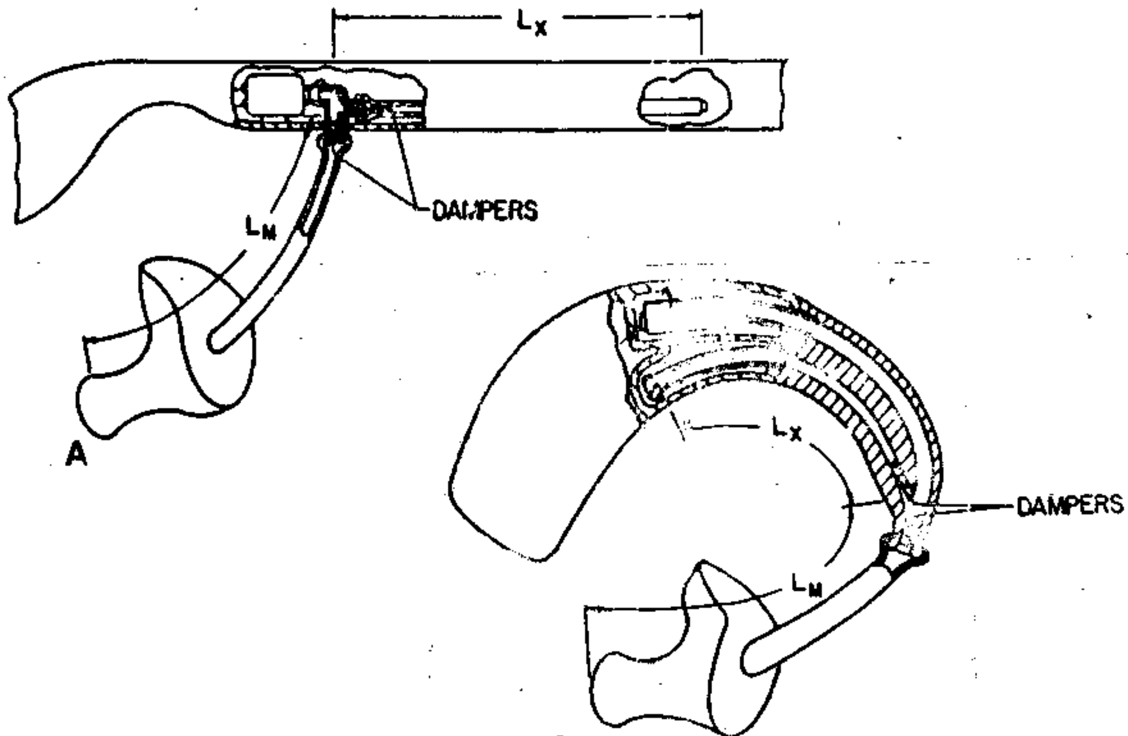


Fig.33: Carlson's twin tube (A) for an eyeglass aid (B) for BTE aid.

Carlson noted that at quarter-wavelength resonanee points, one length of tubing represented a high input impedance, while the other identical length of tubing represented a low input impedance. Thus, a cancellation effect was observed at these reference points. Acoustic damping elements were placed at the intersection of the two tubes to avoid impedance fluctuations and discontinuities at off-resonance points.

III. Horn Effects:

Acoustic horn:- Killion and Knowles (1978), Killion (1981); Brunved (1985) report of the use of acoustic horn principle in heating aid response modification. Acoustic horn, as defined by Brunved (1985) is "a tube of varying cross-section having different terminal areas that provide a change of acoustic impedance". In hearing aids, the horn provides a better acoustic impedance of hearing aid tubing and the relative low impedance of the ear canal. This is accomplished gradually or in steps, increasing the ID of the hearing aid's plumbing, consisting of sound hook, tubing and earmold. The tubing diameters are commonly on the order of 1 mm ID tubing at the receiver, 1.3 to 1.4 mm ID through the earhook, 1.9 to 2 mm ID in the coupling tubing which extends from the hook to (and generally through) the earmold as in Fig.34.

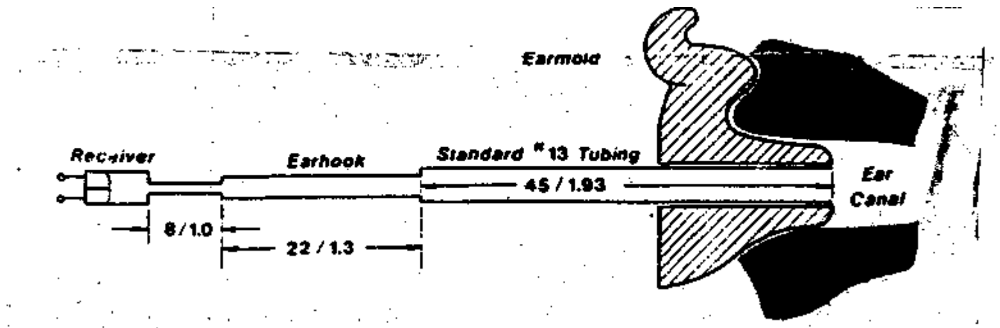


Fig.34: Typical ear-level hearing aid coupling system.

The result is a reclamation of high frequency energy which would otherwise be lost due to poor impedance match. In other words, the use of horn configuration increases the higher frequet cies of the hearing aid response. The effectiveness of a horn is governed by specific acoustic laws with regard to the physical dimensions of the horn. Typically, a plubbing system having a total length of 80 mm and terminating with 4 mm inside diameter at the earmold will start increasing the high frequencies at about 2000 Hz and may show upto 5 dB to 8 dB increment at 4000 Hz Very short horns (for eyeglass and ITE applications) show no high frequency improvement of practical values.

Some useful results from Transmission Line Theory reported by Killion (1981) pertinent to horn effect (tapered line) include:

a) Little increase in the output will be seen at frequencies below the effective'flare cut off frequency' determined by the rate at which the diameter of the coupling tube increases with length. Doubling the diameter every 39 mm, using either a continuously-tapered or a stepped-bore coupling will give a cut-off frequency of about 3 KHz; doublingevery 13 mm (3x the flare rate) will provide a cut off frequency of about 9 KHz etc.

b) The increase in output above the effective cut-off frequency will be approximately proportional to the ratio of the diameters of the outlet and inlet ends of the coupling tube. For instance, a 6R12 used with a wideband OTE aid will provide a coupling system of about 43 mm that starts with roughly 2 mm diameter inlet and ends with a 4 mm diameter outlet at the earmold tip. This 2:1 ratio corresponds to an expected pressure gain of 6 dB above a 2.7 KHz cut off frequency.

i) Libby horn - The Libby Modification of the 8CR earmold was labeled the 4 mm Libby horn. The tube is used without internal dampers, the smoothing of response being accomplished by a damper, typically 1500 ohms placed at the end of the earhook for OTE aids.

Libby made commercially available what is essentially the Killion 6EF dual tubing earmold as a single molded piece labeled the 3 mm Libby horn. (Fig.35).

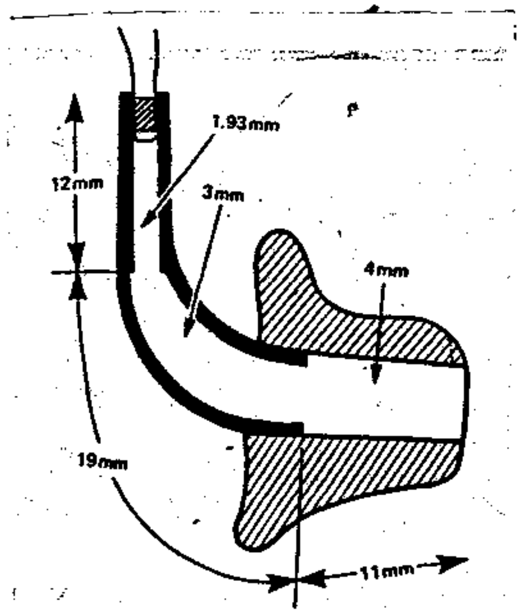


Fig.35: The Libby horn.

The effect of the 3 mm and 4 mm Libby horns with a 1500 ohm damper at the end of the earhook, as a compared to the same 43 mm length of single No.13 tubing without damping is shown below. The change in response as compared to that of No.13 is shown in Fig.36.

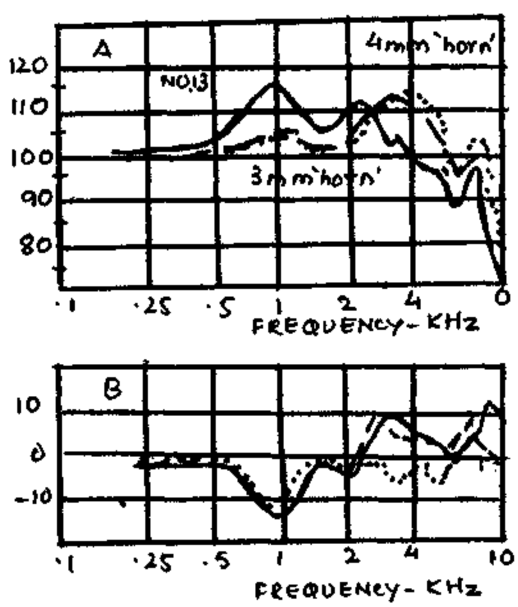


Fig.36: EFFECT OF 3+4mm LIBBY HORN.

BaKke horn - An earmold with a Bakke-hom gives practically the same acoustical performance as an earmold with a Libby horn. In this, the tube is easier to exchange and the mold relatively easier to manufacture. The horn is made of rigid plastic and can be glued directly into a hard acrylic earmold. For use in connection with soft earmolds, another version of the Bakke horn, the BaKke horn's' with a large flange and fastening area is available.

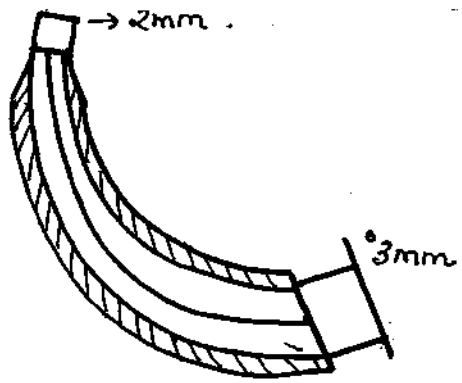


Fig.37: The Bakke horn.

In the case of narrow earcanal, difficulty is encountered, in obtaining a round opening of 4 mm in diameter in the tip of the earmold. A 4 mm round opening is not essential, however. Therefore in the area of the opening, it is possible to benefit from the fact that the ear canal often has an oval cross-section and make the top part of the opening oval or partly without wall, as proposed by knowles and Killion cited by Bergemstoff(1983).

It can be concluded therefore that earmolds with horns give a marked improvement in reproduction of the high frequency sounds especially in connection with wide range hearing aids. In practical testing of earmolds with horns, users have reported that the sound is more pleasing, natural and less tiring and the intelligibility of speech is much better especially in noisy environment (Watson, 1960; Olsen, 1971; Pascoe et al, 1973; Triantos and McCandles,1974) cited by Ely (1981). In addition a family of hearing aid user has observed that the user himself speaks more clearly (Bergenstoff, 1983).

The other devices include -

Exponential horn - (Brunved, 1985) which is a horn with cross-sectional area increasing exponentially with axial distance.

Killion horn - this incorporates acoustic horn usually with damping plug (filters).

Reverse horn - this is a tubing/earmold combination that terminates at the earmold with a smaller ID than that of the tubing, thus rolling off the higher frequencies (opposite of acoustic horn). In other words, it can be used to reduce high frequencies in a prescribed, controlled and reversible manner. The fig.38 represents the cross-section of reverse horn as reported by Ely (1981).

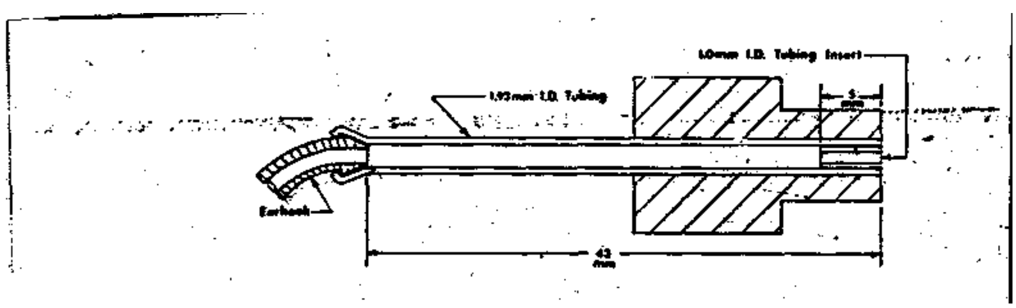


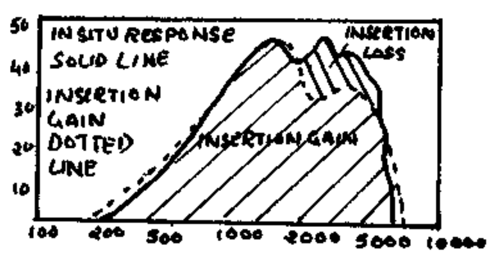
Fig.38: Cross section of the idealized reverse acoustic horn earmold. A 1.0 mm ID tube, 5 mm long is shown inserted into the tip of the mold.

Tucker and Nolan (1984) report that such devices utilizing the horn effect are impractical for use with young children because of the physical size of the ear and associated earmold problems. However, it proves advantageous for older children, particularly those with more severe high frequency hearing loss. Various experimental studies highlight the importance of a good extended high frequency response in relation to hearing -impaired children's speech discrimination abilities (Watson, 1960? Olson, 1971; Pascoe, et al 1973 , Triantos and McCandles, 1974) as reported by Tucker and Nolan (1984). This implies the importance of acoustic horn in the ongoing management of the hearing impaired.

Frequency Gain Modifiers (FGM):

The typical SN loss configuration depicts a high frequency hearing loss with impaired speech discrimination, making the loss a serious handicap. "The goal of a hearing aid then, should be to obtain specific soundpressure levels representing normal hearing" (Bennett, 1983).

In use of the conventional mold, there is a decrease in gain in the range from 2000-3000HZ and natural earcanal resonance decreases as depicted in Fig.39.



Fi9.39: Change of response due to earmold insertion.

To solve this problem, Bennett,(1983) contrived an ear-moldsystem by adding cavities of varying sizes to increase the high frequency output of the aid and mold in combination by 10-20 dB SPL at 3000, 4000 and at times 5000Hz with the FGM system. Belled Canals became a necessary part of this system; the final development being a resonator type earmold with exact stepped cavities of a belled canal. No tubings run through the bore area of the mold (Fig.40). There is a special sealer cap upon which standard or thick walled 6 13 tubing can be attached with ease.

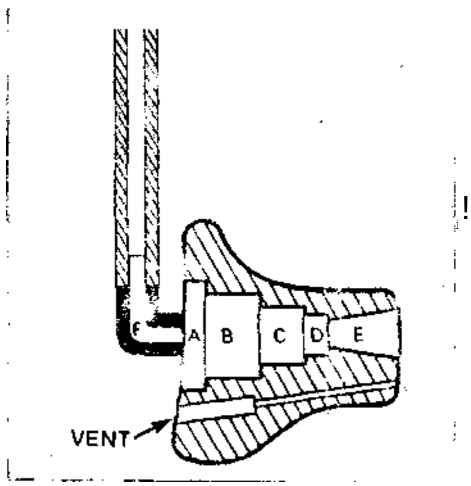


Fig.40: FGM mold.

A family of FGM molds have been contrived to fit the different hearing Boss configurations. The guidelines to use these listed out by Bennett,(1983) include -

1. FGM earmold # 1: should be fitted for moderate to severe hearing loss (45-65 dB). If the patient's hearing is normal

1000 Hz and a large amount of gain is required in the high frequency region this mold can be utilized, only requiring a little looser fitting.

ii) In sound field testing, if more gain is needed at 500 Hz, the FGM mold # 2 should be used. This is the more versatile of FGM molds. Here, increase in gain requirements at 500 Hz necessitates the use of low frequency venting # D. If all the low frequency of the hearing aid is required, but need to relieve some of the pressure in the canal,use vent B. This mold can be used snug or loose, but in most cases used loose. If # 2 is ordered, this will be made loose and with a vent % G, this will cut the low frequencies of the hearing aid to maximum.

iii) FGM earmold # 3 is designed for an open canal type of fitting. It still retains the high frequency cavities with the same amount of gain in the high frequencies as the other FGM molds. The cavities fit in the top of the canal with 3/32" or more opening in the bottom of the canal. This will help cut the low frequencies eliminating the 'stopped up' feeling and help with the complaints of background noises. If the audiogram shows a loss from 35 dB at 1000 Hz to 1500Hz or sound field testing shows a 10 dB to 15 dB gain between the threshold and comfortable level, and if the average tolerance is low, then # 3 will work best.

iv) FGM earmold # 4 is designed for an open type of fitting, the same as # mold, but # 4 eliminates feedback.

Changing the venting size will also change the 500-1000Hz output. This can be done by inserting different size tubings. If the audiogram shows losses of 35 dB at 500 Hz to 55 dB at 1000 Hz to 1500 Hz, this mold ought to be used.

Thus, the system of four styles of earmolds fabricated with Bennett (1981) patented cavity configurations (U.S. patents # 4349003 and # 26659) do cover most fitting needs.

The Killion series of earmolds:

A renaissance in earmold technology has resulted from the contributions of Killion, whose objective was to produce wide - band and flat or smooth insertion response curves (Killion,1979). This work has led to a better understanding of earmold technology as related to improved insertion gain characteristics. Killion's work was aided by the availability of the Zwislocki coupler (Sachs and Burkhard, 1972) and the KEMAR manikin (Burkhard and Sachs, 1975).

In developing an earmold system for an experimental wide - band hearing aid (Killion, 1976), the concept ofusing two dampers in specified locations in the earmold tubing system was conceived (Killion, 1976). The earmold system adopted was termed the 6R10, with '6' designating the cutoff frequency(6 KHz), 'R10' indicating a rising response that was 10 dB higher at 6 KHz than at 1KHz, as measured using an ear simulator (Zwislocki coupler).

The major Killion series of earmolds reported by Killion, 1981, include the following -

1. The 6R12 earmold
2. The 8CR earmold
3. The 6AM earmold
4. The 6BC series of earmold
5. The 16KLT earmold.
6. Modification of the 8CR earmolds by Libby, called Libby modification of the 8 CR.

The following few pages furnish the details of the above mentioned Killion series of molds.

1. The 6R12 earmold (Knowles and Killion, 1978): This earmold was designed to provide a 6 KHz cutoff frequency with a maximum high frequency boost below that frequency and a well damped response throughout. The 'R' stands for 'Rising response'.

The construction of the 6R12 mold is represented in Fig.41 along with the frequency response obtained with it and a conventional mold used with a wide band hearing aid (The greater volume of air enclosed in a large-bore earmold causes a reduction, typically of 1 or 2 dB, in the low frequency output of a wideband hearing aid). As a general rule, the change from a conventional meld (# 13 tubing to the tip of the earmold and no damping) to a 6R12 earmold will produce a 10-15 dB reduction in the height of the typical response peak near 1KHz and about a 5dB increase in output in the 4-6KHZ region.

This construction was labeled the dual-tube 'shell' version of the 6R12 (Knowles and Killion, 1978), a construction that uses a section of ^ 9 tubing to provide the 3 mm diameter portion of the sound channel. This dual-tube version has been more popularized than the original single-tube version, which requires a 'regular* (concha-filling) earmold construction to provide sufficient length to accommodate both the 3 mm and 4 mm diameter portions of the sound channel.

The earmold utilizes the horn effect by going from narrow tubing at one hook to wide tubing at the earmold tip. Itis made as follows:

(i) The 4 mm bore from the tip to the earmold is made 10 mm long.

(ii) A piece of No.9 (3 mm diameter) tubing is placed to begin 10 mm from the tip of the earmold and to extend for 8 mm (The piece of tubing will have to be more than 8 mm long so the next piece of tubing can fit into it. However, the distance from the insertion of the No.13 tubing to the 4 mm opening is 8 mm).

iii) A piece of No.13 tubing is inserted into the No.9 tubing and pushed in far enough to leave an 8 mm length of No.9 tubing. (The total length from the tip of the earmold to the end of the No.13 tubing is 43 mm).

iv) The tubing is glued together, and dampers are inserted. One 680 ohm damper should be placed just beyond the insertion of the No.13 tubing and the other in the No.13 tubing 35 mm from the tip of the earmold.

That users can hear the difference between damped and undamped frequency responses was compared by Lawton and Cafarelli (1978) cited by Killion (1981). They compared speech discrimination score(SDS) and sound quality judgements obtained from a group of 28 hearing impaired subjects listening to speech through hearing aid coupler through conventional and 6R12 earmolds. There was a slight improvement in SDS with the use of the latter plus 24 of their 28 subjects preferred the sound quality with the 6R12 earmold. Moreover, most (21) of their subjects preferred the sound quality of a wideband aid over a conventional (narrow-band) aid. The frequency response of their wideband aid with the two earmold types is shown in Fig.42.

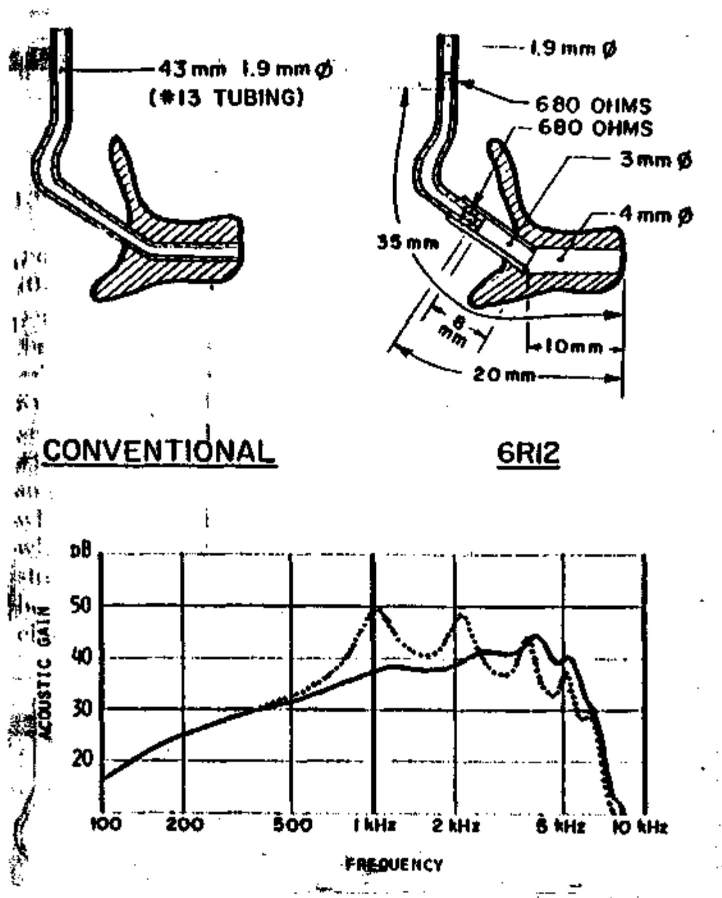


FIG 42 : FREQUENCY RESPONSE – CONVENTIONAL VS 6R12.

In another study by Rezen (1982) subject's communication function was evaluated, combining the use of 6R12 earmold with an extended high frequency range aid. Eleven hearing impaired subjects with mild to moderate hearing losses were evaluated before, during and after a 6 weeks period of use. Results obtained highlighted the increase in functional gain in the high frequencies with a small improvement in speech intelligibility in presence of noise.

2. The 8CR earmold (Killion, 1979) - This mold, making use of the horn effect is designed to provide a high frequency response to 8 KHz with a broad peak at 2.7 KHz to compensate for the loss of external ear and canal resonance caused by closing the earcanal with a mold. Damping provides smooth response throughout. 'CR' stands for canal resonance compensation. Fig.43 shows the construction of the 8 CR and a response curve of a hearing aid using it, as measured an a 2 cc coupler. Also shown is a curve of the estimated 2 cc coupler response required to obtain a flat insertion response.

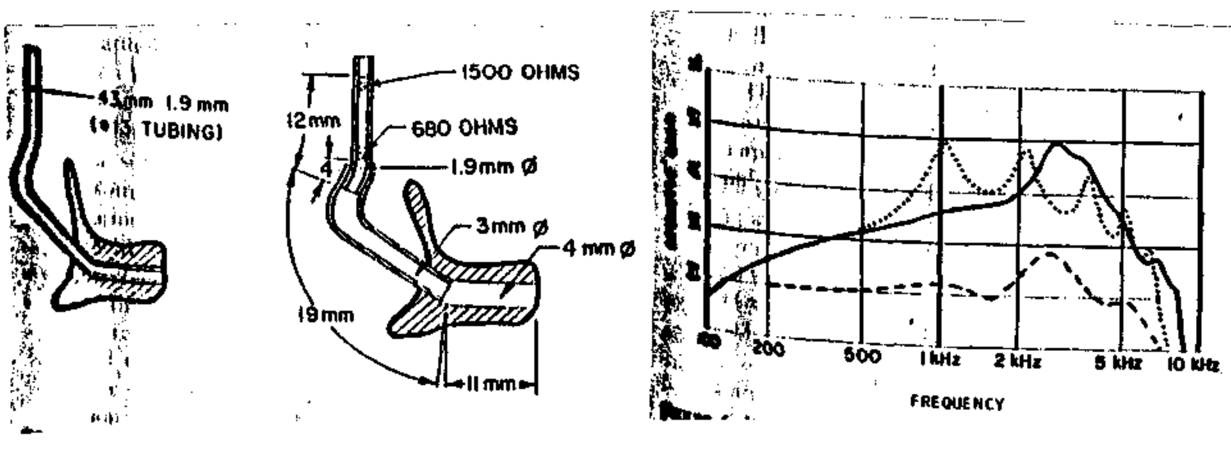


Fig.43: Frequency response of wide-band aid (....) and 8 CR(....) earmold, measured with the 2 cc coupler.

The mold has a 4 mm bore which is 11 mm long beginning at the tip of the earmold. A piece of No.9 tubing is inserted at the opening and extends for 19 mm. A No.13 piece of tubing is inserted into the No.9 tubing to a depth that will allow for 19 mm of No.9 tubing from the end of the 11 mm bore to the insertion of the No.13 tubing. A 680 ohm resistor is placed 4 mm from the beginning of the No.13 tubing and a 1500 ohm resistor is placed so as to end 12 mm after the beginning of the No.13 tubing.

Thus the use of 8CR compensates for the lost earcanal resonance and also provides a moderate upward slope that would be effective for many cases of sensory-neural hearing loss.

3. The 6AM earmold (Knowles and Killion, 1978) - This earmold is a dual diameter tubing vented type, with a damper in the tubing to smooth the response. It is similar in function to the Acoustic Modifier earmold developed by McGee, 1964. This variation has been labeled '6AM' earmold owing to its 6 KHz cut off frequency and its general similarity to the Acoustic Modifier construction. Fig.44 shows its construction and the response obtained with a wide-band receiver on a Zwislocki coupler compared to the response obtained with single No.13 tubing. Here, the vent consists of a single 5 mm long hole of 4 mm diameter. The 3 mm diameter holes side provide nearly the same low-frequency roll off.

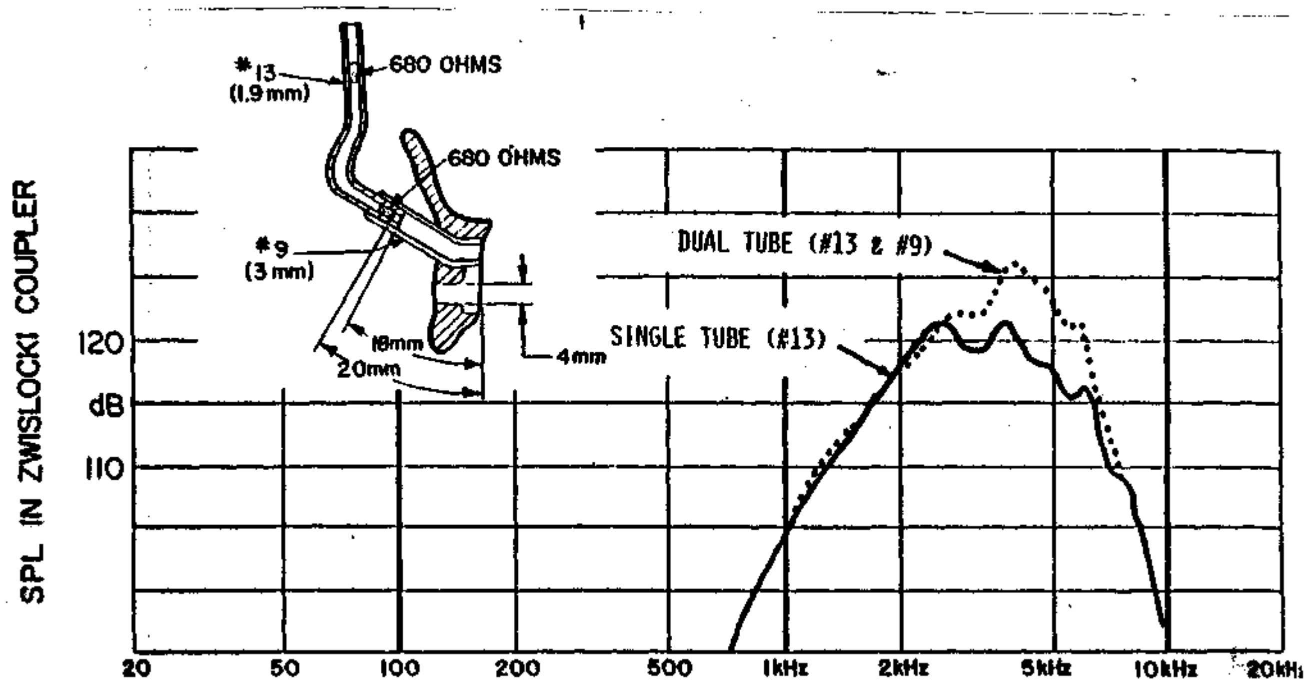


Fig.45:The 6AM earmold_WIDE BAND RECEIVER RESPONSE.

4. The 6BC series of earmolds: The purpose of the 6 B or 6 C earmold design is to provide a systematic method of boosting (6B) or cutting (6C) the high frequency response above about 2 KHz. This is accomplished by changing the diameter of an 18 mm long bore at the ear canal end of the earmold, beyond the no.13 tubing from the aid. Diameters larger than that of No.13 increase highs; diameters smaller than No.13 decrease hights- & similar control method is seen Fig.46 for the 6EF earmold system.

The construction of the undamped 6 BC series earmolds, along with the frequency response curves obtained with a wind-band hearing aid are represented in Fig.47. The undamped 6B10

(Boost 10 dB) earmold has a large diameter 4 mm hole for a full 18 mm. In practice, such an earmold would probably be constructed by cementing a section of # 13 tubing inside a section of # 7 tubing (with a few millimeters of # 9 tubing as adapter) and cementing the composite into a 'shell' or skeleton mold.

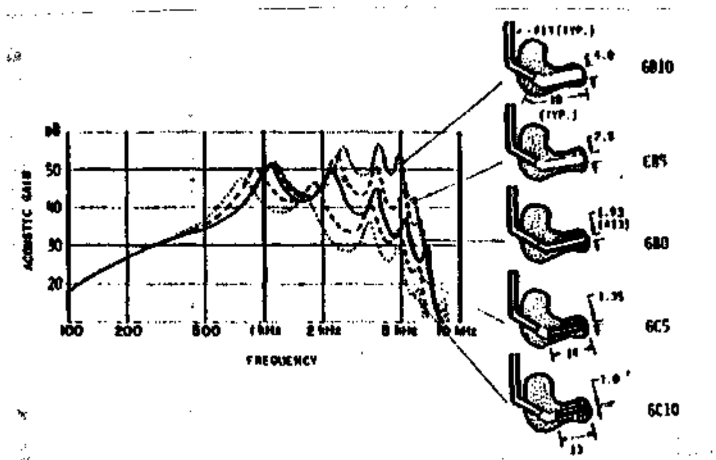


FIGURE 46 - Graduated high-frequency response control using undamped 6BC earmolds with wideband aid.

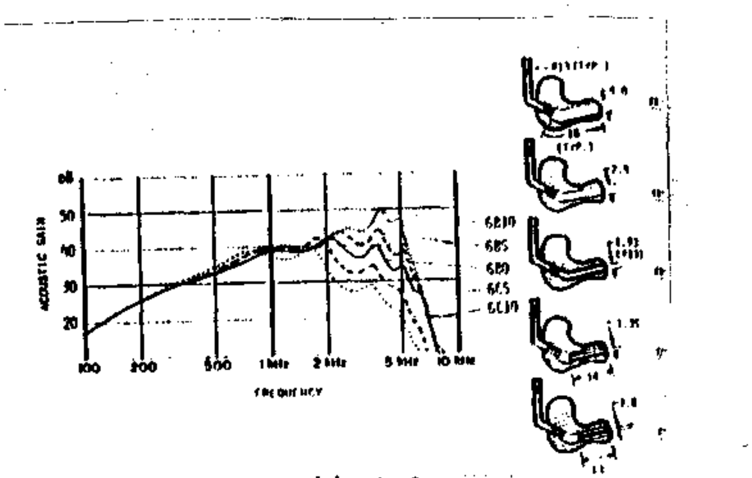


FIGURE 47 - Graduated high-frequency response control using damped 6BC earmolds with wideband aid.

The undamped 6C10 (Cut 10 dB) earmold uses a 13 mm long section of # 18 tubing (l mm ID) cemented inside a 13 mm long section of # 13 tubing (whose ID matches the outside diameter of # 18 tubing), which is in turn cemented in an earmold. The undamped 6C5 uses only a 14 mm section of # 16 standard tubing cemented into an HA-2 type of earmold, but it is otherwise similar to the HA-2 earmold with # 16 tubing insert.

The undamped 6B0 earmold is nothing more than a conventional earmold. It is the 'zero boost' base member of the undamped SBC-series of earmolds.

Any of the 6BC series earmold is assumed to be damped unless it is specifically labeled as an 'undamped 6C10' 'undamped 6B10' etc.

5. The 6KLT earmolds: This is an experimental earmold designed to provide a smooth insertion response out to 16 KHz with an OTE aid having a very wide-band response. Fig.48 shows the construction and a curve of receiver response as measured on an ear simulator. A dashed curve shows the estimated ear simulator curve required to give a flat insertion response. This earmold and receiver would make possible a 'transparent' hi-fi hearing aid which would sound the same as direct listening without a hearing aid for a normal hearing listener.

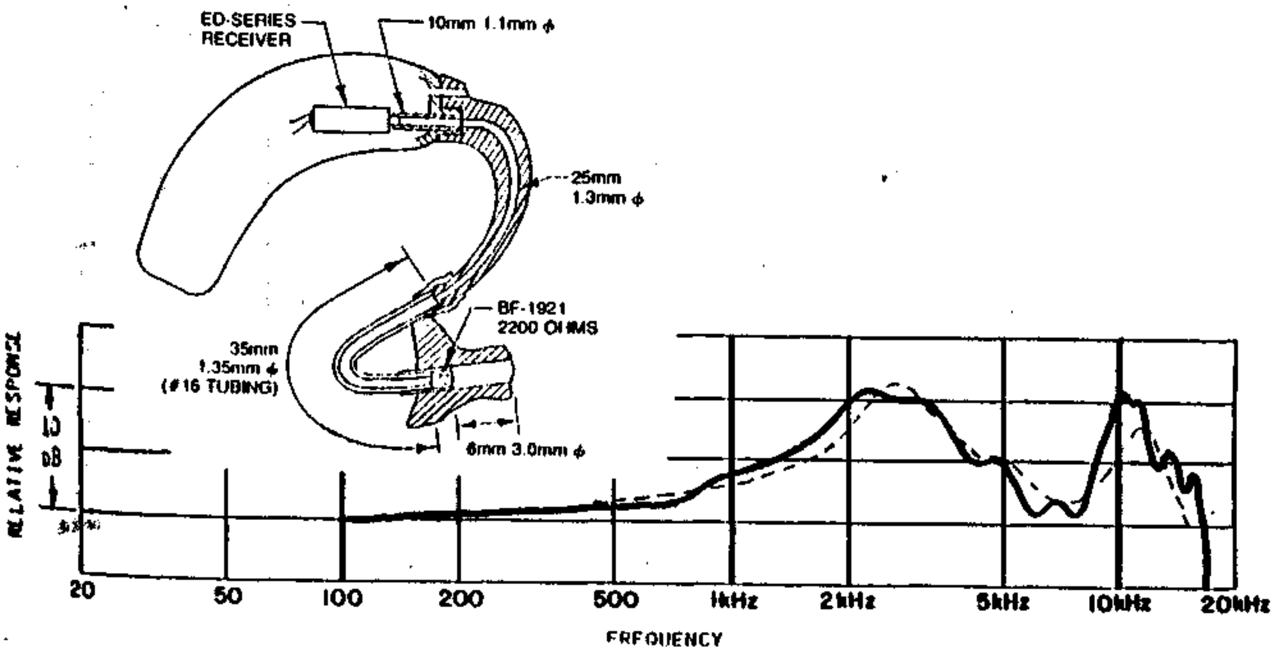


Fig.48: Zwislocki coupler response of typical ED-series earphone in OTE aid with 16 KLT earmold (——) Shape of estimated Zwislocki couplet response required to provide typical user with flat insertion gain in diffuse sound field shown **(....)** incomparison.

6. The 6EF earmold (Killion,1981) - This earmold was designed to work especially well with the Knowles EF receiver, but has found to be effective with nearly all Knowles receivers. It utilizes a dual tubing system, employing 21 mm of No.13 tubing from the earhook to a terminal section 3 mm in diameter and 22 mm long. In addition to the benefits of the basic dual tubing arrangement, the 3 mm final section allows the insertion of lengths of smaller ID tubing to control the high frequency response. The 6EF takes advantage the fact that the outside diameter (OD) of several standard sizes of tubing is 0.116" and that they fit well into the 3 mm

final diameter. For smoothening of the response, a 680 ohm damper is used at the ead of the earhook on an OTE aid. Its location is far enough from the earcanal to avoid clogging by wax.

7. Libby modification of the 8CR earmold: Libby (1981) found that while excellent acoustical results were obtained using the Killion 8 CR earmold, some practical problems arose including -

(i) accumulation of moisture in the tubing (possibly because of the damper's presence),

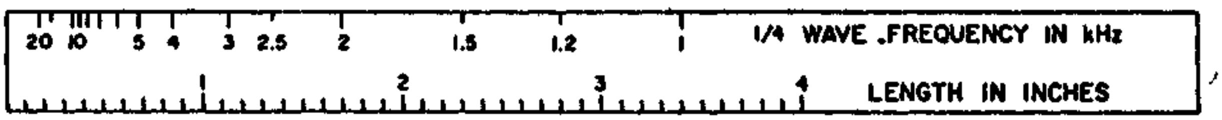
(ii) cosmetic objections to the multiple tubings required,

(iii) the difficulty of joining the tubings with accurate dimension and

(iv) the difficulty of replacing the tubing assembly.

To overcome these difficulties Libby had an earmold tube molded in one piece that was generally similar to the 8 CR. This composite tube was labeled the 4 mm Libby horn. The tube is used without internal dampers, the smoothing of response being accomplished by a damper, typically 1500 ohms, placed at the end of the earhook for OTE aids.

The above earmolds are now commercially available from earmold laboratories. If for a particular patient, resonances at other frequencies are desired, the quarter-wave resonance ruler (Fig.49) may be used to determine the placement of the resonators. The quarter-wave resonance ruler suggests the distance in millimeters and inches from the tip of the earmold at which a resister should be placed in order to obtain the appropriate peak. Extreme care ought to be exercised in placement of the resisters owing to small changes bringing about significant movement of the peak. Trial and error with a number of patients will reveal whether these earmolds offer a clinically significant improvement over the more familiar earmold modifications.



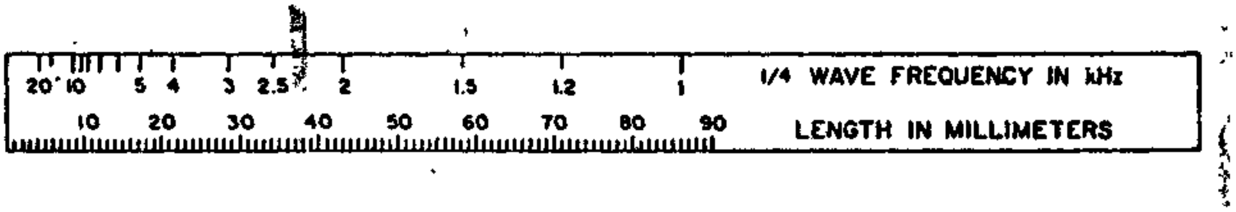


Fig.49: Quarter-wave resonance ruler.

2 KHz earmold design:

As a result of developments in earmold technology, a variety of designs have been specified, perhaps the two most widely known are Killions 8CR and 6R12 molds.

Designed molds utilize bora effects to control the high frequency component and damping to control the aid frequencies, made for mild-moderate hearing losses in adults, constituting the bulk of the demands for hearing aids. However, these molds required modification for other populations. Eg. children having canal bore and pinna dimensions too small to accommodate and 8 CR or 6R12. Efforts are now being made to respecify current mold designs for the smallest ear. Also, those with severe or profound losses may need to have filters removed from their 8CR or 6R12 wolds since the mid frequencies damping may be deleterious.Vith a patient with severe-profound loss with a masstilt it is pressumed that maximum gain is needed in the 2 KHz area, perhaps ranging from 1.5 KHz to 3 KHz. Using the quarter-wave resonance principles provided by Killion, a coupler was designed that adds resonance to the 2kHz area and shifts the primary resonance peak upward in frequency by one third actave - resulting an improvement in the gain characteristics. Since the wave length of 2KHz is about 16 cm, a 2KHz resonance peak requires an abrupt jump or step in tubing diameter at a quarter wavelength i.e.4 cm from bore opening.

Cavity size effects:

Assuming that the volume of the cavity between the tip of the earmold and the tympanic membrane is 0.6 cm in the normal average, ear and that the impedance of the tympanic membrane and middle ear is equal to an equivalent volume of 0.8 cm^3

(as defined by the characteristics of the occluded ear simulator) the 'normal, average adult' earmold (8.3 mm insertion) operates into a total volume of 1.4 cm^3 (Ely, 1981).

With increase in insertion depth, the fallowing features can be noted as reported by Ely (1981).

i) Fig.50 depicts an increase of 2-4 dB occuring across the entire frequency range as the earmold is inserted an additional 8.3 mm deeper into the Zwislocki occluded ear simulator.

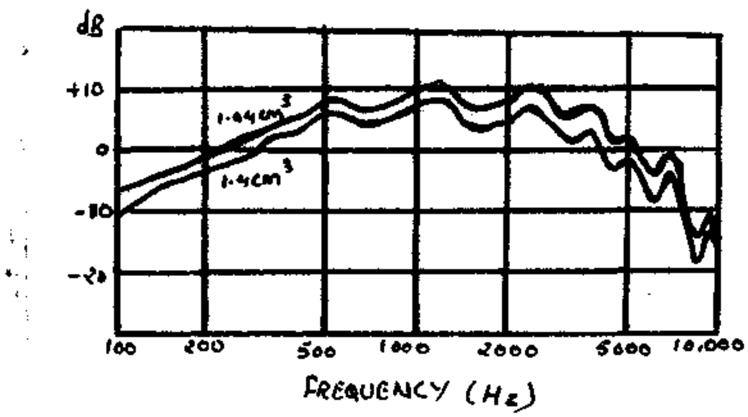


Fig.50: Comparison of SSPL 90 of the ear level hearing aid system with standard insertion depth (1.4 cm^3 Zwislocki coupler volume) and deep insertion (1.04cm^3 volume).

The 0.36 cm^3 coupler volume reduction results in a 2 to 4 dB increase in coupler SPL.

ii) Whenever a hard walled cavity volume is halved, the SPL generated will increase by 6 dB, a factor of 2.

iii) When the volume is doubled, the SPL will decrease by 6 dB.

iv) When, however, the actual volume between the earmold tip and tympanic membrane is cut in half, a less than 6 dB increase in SPL 1 results, because only a portion of the total volume has been halved. The equivalent volume of the tympanic membrane and middle ear remains the same.

Effect of enlarged earmold cavity in front of earphone nub:

Lybarger (1958,1979) investigated the effect of a small eavity at the tip of the button-type receiver used with body aids and auditory trainers, usually the result of overdrilling the hole into which the metal snap ring is heat pressed. If the hole is drilled too deeply, a cavity results between the tip of the button earphone sound outlet and the smaller sound bore through the earmold. The set of response curves in fig.51. demonstrated the effect of increasing the volume in 100mm steps Which highlights that the highs are systematically reduced with a corresponding downward shift in the primary earphone resonance from 2500 Hz to 2100Hz. This implies that cavity of minimal depth be ensured to provide the broadest possible response to the hearing aid user. This is also a technique utilized in reduction of high frequencies delivered to the ear where that is desirable, for instance when attempting to control high frequency feedback. Additional high frequency reduction along with a downward shift of the resonant peaks can be achieved by decreasing the diameter of the sound bore through the mold (Lybarger, 1958).

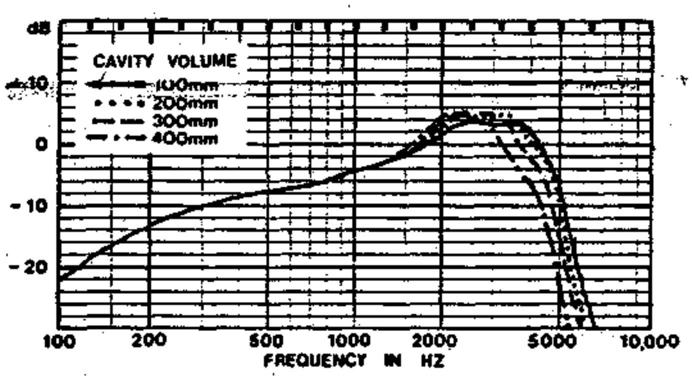


Fig.58: Effect of a small cavity at the tip of a button type hearing aid earphone. The high frequency response is systematically reduced as the cavity volume is increased in 100 map steps.

Temporary foam plug earmolds:

In many instances, trying several different molds within a short span of time is advantageous, when ordering custom mold, for each of these constructions becomes impractical. This is when the temporary foam-plug earmolds gain importance. Of the acoustical modifications of the temporary foam plug earmolds, the stepped-diameter temporary earmolds and the venting temporary foam-plug molds, as reported by Killion(l98l)have been discussed.

1. Stepped-diameter temporary earmolds (Killion,1981):

The stgpped-diameter temporary eamolds are readily assembled from telescoping sections of plastic tubing. The # 9 and=a7 sizes of PVC or 'vinyl' clear plastic insulation tubing (available from most electronic supply houses) provide, along with # 13 standard pre-bent tubing, a telescoping set of tubings; the # 13 tubing fits inside # 9 tubing which in turn fits inside the # 7 tubing. A 3/16" paper punch will produce a hole, in a pre-flattened foam plug, suitable for either # 9 or # 7 tubing.

In the construction of any of the earmolds using telescoping tubing sections, it is of importance to keep in view that the only thing that affects the sound is the sound channel itself. For instance, an HA-2 type of earmold is readily assembled from a section of # 13 tubing, approximately 28 mm long and a section of 3 9 tubing approximately 22 mm long, with the # 9 tubing slipped over the # 13 tubing a distance of 4 mm. This leaves an active length of 18 mm of 4 mm internal diameter sound channel (22 minus 4 am of # 13 tubing) at the ear canal end of the earmold. Likewise, when the # 13 tubing is slipped over the earhook of the OTE hearing aid, the active length of # 13 tubing will be about 25 mm (allowing 3 mm overlap of the tubing over the end of the earhook). These dimensionsof section length ought to be adhered to.

Damping elements can be inserted in the # 13 tubing portion of telescoping - tube style earmolds by using the back end of a # 50 drill bit or a short length of 1.9 mm diameter tight - coiled spring as a push rod. In either case, stopping at the proper location is made easier if the push rod is first inserted into a clamp or 'pin vise' and locked into position so that exactly the proper amount of push rod protrudes. The individual location of two damping elements is less critical than the location of a single element. An error of 1 mm either way in the location of either of two dampers will have minimal effect on the frequency response. Large location errors should be avoided if consistent results are to be expected.

2. Venting temporary foam-plug earmolds:

Minimal diameter vent is useful for barometric equalization or to reduce the low frequency output of the aid. Venting, in a temporary foam plug is readily accomplished by punching an additional hole and inserting a vent tube with the desired internal diameter. With a vent tube equal to the typical 20 mm length of the foam plugs, a # 13 tubing section will give roughly a 550Hz cutoff; a % 16 standard tubing section, a 400 Hz cut off and a # 18 tubing (cemented inside a section of # 13 tubing to provide the proper OD section will give roughly a 300 Hz cut off. Shortening the foam plug and vent tube to a 10 mm length (by cutting them in half) will produce a 40% increase in each of the cut off frequencies given above.

For pressure - relief purposes, a 20 mm section of # 24 tubing (cemented inside a section of # 16 standard tubing to provide the proper OD will provide a cutoff frequency of roughly 150 Hz. When cementing tubing sections together, care ought to be exercised not to block the sound channel with the cement. With the smaller tubings such as # 18 and # 24 blocking can be avoided if an excess length of the smaller tubing is cemented into the larger one and the two ends are trimmed flush after the cement has cured.

Summary:

Various acoustic modifications can be achieved by altering the physical characteristics (dimensions), of the earmold like change in length, internal diameter, tubing and vent alterations, introduction of resistive acoustic dampers and horns. These acoustic modifications do not bring about a drastic change in the response characteristics of the aid, but rather result in a radical increase in subjective user comfort complying both with acoustic and physical needs. These for instance, include -

1. a very small vent (0.031") which does not alter the frequency response, but provides a means of barometric equalization between the external auditory meatus and the atmosphere.
2. When use of vents is contraindicated owing to acoustie feedback, a narrower earmold canal bore and have the same effect by providing extra displacement of the amplified sound away from tympanic membrane.
3. User comfort can be improved, and complaints of fullness alleviated by shortening the canal length. This also aids in reducing complaints of amplified sound being too reverberant or loud.
4. Acoustic horn principle can be used to improve the high frequency response.
5. A reverse horn may be employed to reduce high frequencies in a prescribed, controlled and reversible way.
6. Lastly, Lamb's wool an Sintered filter etc. can be employed to damp the resonant peaks or to reduce the tinny or sharp quality of amplified sound.

Table-9: The effects of coupling modification/hearing aid response (Langford, 1975).

Modification 1.	Effect on low frequencies (<750 Hz) 2.	Effect on primary peak (750-1500 Hz) 3.	Effect on secondary peak (1500-3000 Hz) 4.	Effect on high frequency (>3009 Hz) 5.
Longer bore	Negligible	Moves peak to lower frequency	Moves peak to lower frequency and raises height.	Negligible
Short bore	Negligible	Moves peak to higher frequency.	Moves peak to higher frequency and decreases height.	Negligible
Longer canal	Increases the overall height of the response curve.			
Shorter canal	Decreases the overall height of the response curve.			
Very small vent primarily for releasing sound pre- *sure(0.031")	Negligible	Negligible	Negligible	Negligible
Small vent (0.042")	Decreases	Negligible	Negligible	Negligible
Medina vent (0.064")	Decreases	Increases peak height	Negligible	Negligible
Non-occluding mold(CROS)	Eliminates	Moves peak to higher frequency and increases height.	Increases peak height	Negligible

1.	2.	3.	4.	5.
Open vented mold (high frequency)	Decreases	Reduces peak height	Negligible	Negligible.
Sintered filter	Slightly decreases	Large reduction	Large reduction	Slight decrease
Lamb's wool	Decreases over all height of response curve.			

Table-10: Average effect (dB) of earmold configuration on the output of a hearing aid measured in a Zee coupler (HA-2). These values should be added to hearing aid output (dB SPL).

Earmold	Frequency						
	250	500	1000	2000	3000	4000	6000
HA-2coupler snap ring earmold with 18 mm-long sound bore with ID of 3 mm; or earmold with # 13 tubing that is cemented into a sound bore 18 am long, 3 mm ID (almost same as 3 mm Libby horn).	0	0	0	0	0	0	0
Libby hom(4 mm)	0	0	0	0	6	3	3
Constant diameter sound channel snap-ring ear-mold with 1.5 mm ID sound bore2.	0	0	2	-5	-10	-12	-12
Earmoldwith #13 tubing (1.93 mm ID) to tip of earmold (most common model)[3].	0	0	0	0	-6	-7	-6
Open mold (IROS) # 13 tubing[4]	-36	-24	-12	0	-2	-7	-6
Libby horn (mm)[5] vented earmold	-36	-24	-10	0	10	3	3
Barmold with #13 tubing, short hollowed-out bore, and PVV with largest hole.	-24	-2	4	0	0	0	0

1.Killion 1985.

2.Lybarger 1978, Klllion, 1985

3 Killion 1981, 1985 (negative values at 3-6 KHz are due to # 13 tubing)

4 Lybarger 1979

5 Mueller, Schwartz, and Surr, 1981.

6 Lybarger, 1979

CHAPTER-5

TUBING FOR HEARING AIDS

Introduction:

All personal amplification systems, other than the body-level and all-in-the-ear type utilize plastic tube to couple the hearing aid and the earmold. Tube fitting of hearing aids also describes the practice of substituting for the normal earmolds a plastic tube extending into the external auditory canal for the purpose of directing amplified sound to the tympanic membrane. (Stabb, and Nunley, 1982).

Rationale:

The rationale behind tube fitting is to obtain maximum amplification in the desired frequency region without occluding the ear and without getting an acoustic feedback (squeal). Thence the tube fitting attempts to take maximum advantage of

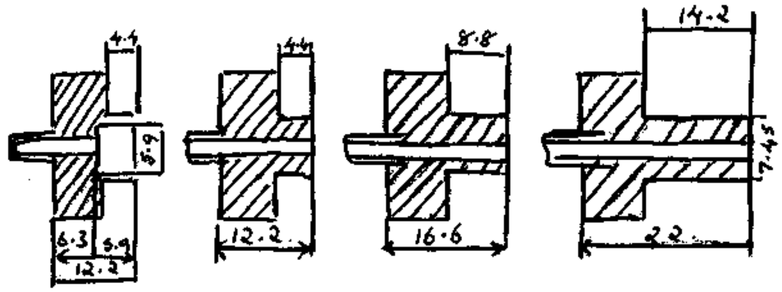
i) Natural resonance of the ear canal,

ii) Of low frequency suppression created by this form of maximum venting,

iii) Elimination of the insertion loss created by placing an earmold in the ear canal.

Tubing type molds:

The tubing type molds, occluding the ear canal are represented in Fig.52. The dimensions given are representative of actual earmolds. They are also such that the medium length tip has the same length as the earcanal extension from the bottom of the concha to the face of the ear simulator in the KEMAR manikin (Burkhard and Sachs (1975), cited by Lybarger 1985). The short-hollowed tip is representative of molds that have short, large diameter vents.



Fia.52: Suggested categories for tubing type earmolds (Dimensions are in millimeters)

Tubing specifications:

A standard series of tubing sizes has been established by NAEL (Blue, 1979) reported by Langford, 1975; Leavitt, 1984; Lybarger, 1985; Mynders, 19%) The sizes are listed in table-11.

Table-11: NAEL tubing sizes.

NAEL standard Size No.	Nominal inside diameter (ID)		Nominal outside diameter (OP)	
	Inches	m.m.	Inches	m.m.
12 Standard	0.085	2.16	0.125	3.18
13 Standard	0.076	1.93	0.116	2.95
13 Medium	0.076	1.93	0.122	3.10
1* Thick	0.076	1.93	0.130	3.30
14 Standard	0.066	1.68	0.116	2.95
15 Standard	0.659	1.50	0.116	2.95
16 Standard	0.053	1.35	0.116	2.95
16 Thin	0.053	1.35	0.085	2.16

Of the above, No.13 is more widely used, with the ID of 0.076".

The above tubings are Made from special formulations of polyvinyl chloride, compounded to give the needed flexibility and colour and to reduce the leaching out of plasticizers by perspiration as much as possible.

Special tubing systems:

1. Dual tubing systems: - This takes advantage of the fact that when there is a significant step-up in tubing diameter towards the earcanal, there is a quarter wave open end resonance in the larger bore tubing that exits into the ear canal. Thisproduces an increased broad response in the high frequencies. Dual tubing systems have been used commercially since 1970. (Lybarger, 1972). The two arrangements as shown in figure 53 were employed. In one form (left), the drilled hole in the earmold was made 3 mm in diameter. The tubing from the aid was cemented in place with 16-19 mm of large bore left free. The tubing used was no.15. In the 2nd form (right a piece of No.ll tubing (2.4 mm ID) was continued out of the mold, telescoped over No.15 tubing and cemented. The smaller tubing led to the exit nuh of the hearing aid. The total length of the 2.4 mm bore was about 25 mm. Both the arrangements proved effective in improving high frequency response compared with

that obtained using no.13 tubing alone. This arrangement can be used for open mold applications also.

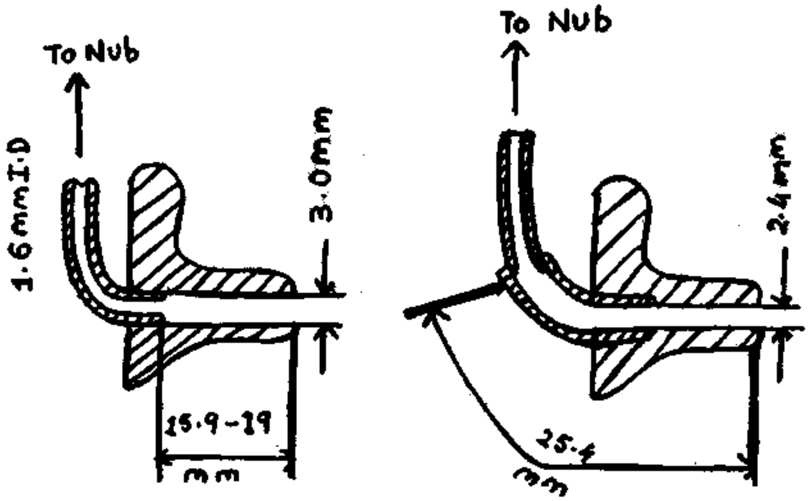


Fig.53: Dual bone tubing arrangements commercially introduced in 1970.

2. Continuous Flow Adapters (CFA) series of earmolds:-

This series was developed by Norman Schlaegel, 1982, "CFA is a tubing invention that coupled with specialized drilling of the body of the earmolds, offers dispensers a new simplified method of using the acoustics of the new earmold technology with a very convenient snap - on adapter for Cubing replacement" (Mynders, 1984).

In the tubing systems, crimping, enlarging or shrinking these has a concomitant effect in the frequency response pattern. Schlaegel's method was to achieve more uniformity by creating a consistent tubing diameter called CFA. The reason for this system to be called 'adapter' was that schlaegel standardized the method of attaching the tubing to the earmold itself, i.e.

the tubing and the adapter are always the same. When the molds are processed, a hard plastic ring is imbedded in the mold itself. The CFA tubing and adapter are then snapped into this securely. By snapping tubing into position, all gluing is eliminated.

The acoustical factors that are a part of this family of earmolds include -

1. High frequency emphasis which promotes better understanding in noise and heightens clarity of speech. Also when this earmold is employed in a fitting, the client reduces the volume control setting to a lower level than if a standard earmold channel is used. The overall benefit is a better signal to noise ratio.

2. Smoothness of the frequency response curve generated - smoothness without sharp peaks and valleys.

3. Consistency/standardization of acoustic effects, from one earmold to another - that is minimal mold-to-mold variation.

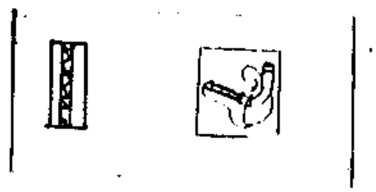
4. Ability of the dispenser to modify the earmold for its comfort without loss of the special acoustic effects.

Technically, the (CFA is unique, having a uniform ID from tip of the adapter to the end of the tubing. The ID is unchanged even when the adapter is in place in the earmold. The uniform ID is responsible for the continuous flow of amplified sound which in turn results in smoothness, consistency and high frequency emphasis of the coupling system. This can be used with all styles of earmolds with either aoft or lncite material.

The options available include seven configurations - the selection chart comprising of:

Earmold style   Venting (in inches)

1   Small open bore   1A - no vent.



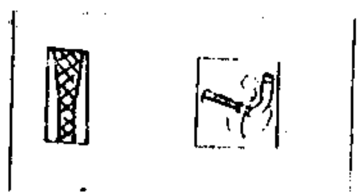
Sound bore 0.076   1B - 0.046

1C - 0.060

1D - 0.076

EFFECT: Duplication of what hearing aid produces. No farther amplification of high frequencies.

2   Bell or horn   2A - no vent



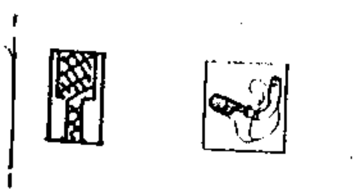
Sound bore 0.125   2B - 0.046

from canal end to   2C - 0.060

then 0.076 to CFA adapter.   2D - 0.076

EFFECT: slight increase in high frequencies.

3   1/2   BORED OUT.   3A - No vent



sound bore 0.187   3B - 0.046

from canal to   3C - 0.060

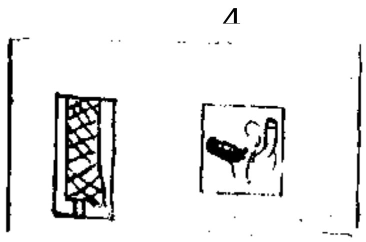
mid earmold   3D - 0.076

then 0.076 to

CFA adapter.

EFFECT: Greater increase in high frequencies.

- 4



LARGE OPEN BORE 4A-No vent

Sound bore 0.107 4B-0.046

4C-0.660

4D-0.076

EFFECT: Acoustically amplifies high frequencies to the maximum. CFA earmold style.

MC

MICRO CROS

Non-occluding.

Long canal, fits to top of canal

EFFECT: Slightly more power than regular CROS mold; sound folio top edge of canal. ADDED CFA FEATURE - tubing can be easily removed for any changes needed.

5

REVERSE CURVE

Open vent

Short canal, large bore with large vent into bore.

EFFECT; accentuates lows and reduces highs.

REVERSE CURVE ADAPTER ONLY.

COMMONALITY IN PERFORMANCE:

1. The CFA # 1 has a performance characteristics comparable to the killion 6R12.
2. The CFA # 2 performs like a Libby horn.
3. The CFA # 4 is comparable to the FGM
4. CFA-MC is comparable to Janssen style mold.

3. . <u>Rectification of collapsed mold phenomenon</u>:-

Salman (1983) reports that stepped bore diameter of earmold tubing coupled with a hearing aid having a wide band transducer results in (1) Enhancement of high frequency response. (2) Compensation of external ear effects (EEE) or loss of canal resonance in earmold resulting from presence of mold in the canal (eg. Killion 8 CR and 8 CR with Libby Horn). Clients using these molds complain of clogging resulting in total/partial blockage of sound, which could immediately and completely be alleviated, restoring the sound transmission by wide mouth opening. Ruling out the otorhinolaryngologieal conditions of wax, eustachian tube dysfunction etc, it was hypothesized that the collapsed phenomenon was due to (i) The widest and softest point of mold tubing terminating in the ear canal, (ii) In this vicinity (tubing terminal), theear canal is narrowed or at near the isthmus.

Removal (cut) of the last (most medial) one-sixth of an inch of the earmold material was reported to be useful in alleviating the cloging - hence the restoration of sound transmission.

Two patients also imported of increased clarity of speech and decreased feeling of pressure. This modification did not result in feedback, probably because of the snug fit of the lateral part of the earmold and because the modification affected only the most medial portion of the mold.

Criteria for tube fittina:

Consideration for tube fitting encompasses the following four conditions:

1. Audiologic
2. Otologic
3. Psychological and
4. Practical.

1. **Radiological indications:**

i) For patients with tolerance problem as in Meniere'a syndrome.

ii) For patients with precipitous high frequency or ski-sloping loss as in noise - induced hearing loss (NIHL) with normal thresholds through 1500 Hz with a drop starting at 2000 Hz.

iii) Unilateral loss with CROS fitting or sometimes BiCHOS fitting (depending on severity of the loss in the better ear).

iv) For cases having adverse effect on hearing in presence dE noise.

2. **Otologic indications:**

These include the conditions where in the use of earmolds is contraindicated or not feasible as in -

1) Existing, chronic or potential outer or middle ear pathology (eg. psoriasis, eczema, external otitis, otitis media etc).

ii) Tympanic membrane perforation.

iii) Presence of radical cavities.

iv) Trauma to concha or helix

v) Referred otolgia.

vi) Otelgia caused from intolerance for closed-mold fitting,

viii) Allergic reactions to plastic materials in contact with ear canal.

viii) Malformations of pinna.

3. **Psychological considerations:** These usually relate to

i) Fullness of ear effect

ii) Inability to tolerate one's own voice

iii) sensation of wanting to hear a more natural sound (unamplified low frequencies and amplified high frequency sounds).

iv) Loud sound tolerance relief

v) Tube fitting also satisfies the cosmetic or vanity considers tions of not having an earmold in the ear.

4. **Practical indications :-** These include factors like -

i) Comfort

ii) On the spot amplification without the need to wait for the earmold

iii) Ease of putting on the hearing aid without the associated problems of correct earmold insertion which is true only for the thick-walled tubing. Onthe contrary, a thin - walled tubing is collapsable, posing greater difficulty in insertion than an earmold. This aspect is of importance for cases having problem with digital dexterity and poor vision, especially the geriatrics.

iv) Other practicalities include modification of hearing aid performance beyond the confines of electrical controls on the hearing aid.

v) Continued build-up of moisture in the usual hearing aid-plumbing system being alleviated by the use of tubing.and relief of the plugged feeling.

vi) A need to be able to switch off the hearing aid in some situations without becoming sound isolated with the hearing aid still in position.

vii) Most vital of these factors is the cosmetic acceptability especially among the younger generation.

Acoustical effects of tube fitting:

Application of tube fitting to the personal amplification system aids in acoustic modification of the hearing aid output which are beyond the circumscription of electrical controls of the hearing aid. These include, as listed by Langford (1975), Stabb and Nunley (1982), Leavitt (1984), Lybarger (1985), Skinner, (1988) -

i) The provision of low frequency suppression and hence the problem of upward spread of masking and reduction of back ground noise amplification. Thence tubing facilities hearing aid usage in presence of noise.

ii) The maximum low frequency reduction achievable with tube fitting is approximately 30 dB at 500 Hz (Stabb, Nunley (1982).

iii) Maintenance of response carve regardless of the input level. For example, the frequency response curve obtained with a low input SPL replicates the saturated sound pressure level-90 (SSPL-90) output curve.

iv) There does not appear to be an ideal response curve for tube fitting common to all hearing aids.

v) Greater low frequency suppression and thereby a high frequency emphasis is brought about by narrowing the ID of the tubing.

A thinner tube provides for an increase in gain at frequency below about 1000 Hz and a reduction in high frequency owing to the acoustical loss in the thin tube.

vi) Larger the outside diameter of the sound tube, greater is the low frequency gain, being especially true inthe 700-1500 Hz region. Conversely, thinner the sound tube is relative to the ear canal, steeper is the frequency response curve.

vii) Tubing insertion depth of less than about 15 mm is considered unacceptable owing to its dislocation from the ear canal during mastication. Also, this brings about a reduction in the functional gain of the frequency response and is more prone to acoustic feedback.

viii) Shorter ear canal tends to provide for more high frequency energy than do longer ear canals. Short ear canals place the response peak at higher frequency because the peak frequency occurs where the measured length of the ear canal effectively equals one-fourth of wavelength.

ix) The distance of the tubing from the tympanic membrane(TM) affects the aignal strength - the closer the tubing to the TM, stronger is the signal, especially so in the lower frequency region,

x) The wider the ear canal is in comparison to the OD of the tubing, the greater the risk for feed back.

Summing up, the 3 primary effects of tubing diameter using either coupler or ear simulator are -

i) To move the first response peak downward in frequency as the ID of the tubing decreases,

ii) To reduce the middle and high frequency response as the diameter decreases and

iii) To reduce the heights of the peaks as the diameter decreases. The latter effect is attributable to increased acoustic resistance caused by air frietion on the walla of the smaller sizes of tubing.

The ID of the tubing can be used as a means of shifting emphasis from higher to lower frequencies or vice-versa. Smaller diameter tubing can also be used as a means of reducing average saturation output and gain.

Table-12: Tubing modification on hearing aid responses:

Modification 1.	Effect on lew frequencies (below 750 Hz) 2.	Effect on primary peak (750-1500 Hz) 3.	Effect on secondary peak (1500-3000 Hz) 4.	Effect on high frequencies(above 3000 Hz) 5.
Long tubing	Increases	Moves peak to lower frequency	Moves peak to lower frequency and increased height.	Negligible
Shorter tubing	Slightly decreases.	Moves peak to higher frequency	Moves peak to higher frequency and increases height.	Slightly increases
Larger ID tubing	Negligible	Moves peak to higher frequency	Moves peak to higher frequency and increases height.	Negligible
Smaller ID tubing.	May reduce below 1000 Hz.	Moves peak to lower frequency	Moves peak to lower frequency and reduces height.	Minimal
Larger diameter bore.	Negligible	Moves peak to higher frequency	Moves peak to higher frequency.	Increases
Smaller diameter bore	Negligible	Moves peak to lower frequency	Moves peak to lower frequency.	Decreases.

Applying tube fitting:

Whether or not the tube fitting as deemed applicable rests primarily on the degree and type of hearing loss encountered.

Degree of loss - As recommended by Stabb and Nunley,M982) essentially, tube fitting can be considered for individuals having a speech Reception Threshold (SRT) upto 50 dB in a variety of audiometric configurations. At approximately 60 dB SRT, an earmold should be considered as the coupling system. Exceptions to this include individuals with preaby-acusis despite SRT being beyond 60 dB and in cases with severe hearing loss especially for those with low tolerance level.

For cases falling under tubing acceptability criteria, Stabb and Nunley, (1982) recommend that one start with # 15 tubing and then move on to larger diameter tubing, depending on the user's reaction and test results. When going as down as # 16 tubing with thin wall, extreme caution is to be exercised unless the ear canal is very small owing to the tendency for acoustic feedback at low volume control settings.

Type of loss - Typical hearing loss amenable to tube fitting are primarily the discharging ears (conductive loss) or SN loa*e* of a variety of configuration including the precipitous high frequency ski-slope losses and those associated with Meniere's syndrome. In Meniere's syndrome, a reverse curve response hearing aid is often used with the tube fitting. It is also recommended for saucer-shaped audiometric configurations.

On the contrary, tube fitting may not prove useful for an all-time hearing aid user, with an earmold as the coupling system owing to the misconception of threatened security that "hearing aid will fall out". Patient counselling helps; in alleviating this concern.

It is not apt for individuals who see very little difference over time in their discrimination performance and their physical comfort from wearing the tube fitting. Moreover, patients who have been successfully fitted with a vented or closed earmold prefer greater low frequency amplification than is available with tube fitting. Although optimal sound field performance may be achieved with an open mold fitting with these individuals, they feel that their discriminatory ability is reduced due to the decreased sound power. Typically, young children are not prime candidates for tube-only fitting. Also, pmysons with hypersensitive ear canal refuse to allow insertion and soldering into the ear canal for shaping. Finally, with hearing loss exceeding 50 dB, a patient generally does not achieve optimal benefit with a tube fitting.

Briefly stating, the only contraindications for tube fitting are the resultant acoustic feedback and lack of optimal amplification benefits.

Testing for tube fitting:

Is the hearing aid really working is a problem frequently confronting an individual with tube-fitttd hearing aid system requiring appropriate justification by the dispensing audio-logist. This discrepancy regarding the functioning (or other-wise) of the hearing aid can be attributed to realizing only subtle or no mechanical amplified sound quality, and since hearing in low frequency region is intact, theymay exhibit few of the hearing loss symptoms of other types and the degree of hearing impairment. Further more, tube fitting being tested in a quiet environment seldom shows an SRT improvement.

HENCE IT IS IMPERATIVE THAT BINAURAL CONSIDERATIONS AND TESTING IN PRESENCE OF BACKGROUND NOISE BE GIVEN DUE CREDITS.

The following protocol for tube fitting in difficult listening environment has been outlined by Stabb and Nunley (1982).

i) Obtain an unaided speech discrimination score.(SDS)

ii) Test the speech discrimination in competing noise at :

a) A plus 10 dB signal-to-noise (S/N) ratio and

b) 0 dB s/N ratio.

iii) Continue to test at lower S/N ratio until a point of breakdown which is that point at which 50% of the words are missed.

iv) Select a hearing aid that handles the lower S/N ratio before breakdown.

CHAPTER - 6

GOOD FITTING EARMOLDS

Increasing awareness of importance of earmolds as an integral component of a wearable hearing aid has seen a resultant technological advancement in this field, and yet an increasing dissatisfaction with the provision of earmolds for the paediatric population in particular. This, according to Nolan (1978, 1986, 1987) has been attributed to (especially for children where the potential benefits for linguistic development, of early identification of hearing impairment can be frustrated by inadequate earmold provision) the following -

1) Poor quality of acoustic fit and discomfort onwearing.
ii) An unacceptably long delay in providing the earmold.
iii) Lack of skilled professionals to take accurate ear impressions.
iv) Lack of awareness of available resources, ear impre-ssion and earmold materials,
v) Total lack of understanding that the earmold is a customized prosthesis specific to each individual hearing aid user.

This highlights the importance of good earmold, the requirements of which have already been highlighted in Chapter-2.

Making good fitting earmolde:

The two distinct types of earmolds in use, namely the

INSTANT or DIRECT end TWO STAGE or INDIRECT, involve different procedures for its fabrication represented below:

Instant or direct type -

EAR IMPRESSION------> PROCESS-_> FIT

Two stage or indirect:

EAR IMPRESSION__>PLASTER CAST__>MOLD CAST--—>PROCESS--—>FTT

Factors influencing acoustic fit and comfort as listed out by Nolan and Tucker, 1984.are -

a) Impression material
b) Impression maker
c) Impression technique
d) Earmold maker
e) Earmold manufacturing technique? the primary requisite being an accurate ear impression.

Taking ear impression:

Requirements:- As listed out by Loavenbruek, 1981, the basic equipments necessary to take earmold impression include -

* Otoscope - to examine the external auditory eanal prior to and after taking the impression.
* Impression material (liquid and powder)
* Glass beaker to mix the impression material.
* Spatula with which to stir the impression material
* Impression syringe kit(a) to introduce the impression material into the canal.

* Otoblocks or cotton ties to be used to form a block in the auditory canal prior to the insertion of impression material.
* Ear light to assist in inserting the cotton block.
* Timer or watch to time the length of time the impression remains in the ear.

Getting an accurate impression rests on

1. A fundamental knowledge on the part of the clinician of the anatomical landmarks of the external ear relevant to the earmold.
2. An ability to interact positively with the child and the parent.
3. A knowledge of the technique to use in obtaining an accurate impression of the ear.
4. An awareness of the importance of using the most appropriate ear impression material.

Ear impression technique: The steps involved in taking an ear impression as reported by Hoffman, 1964; Fifield and Earnshaw, 1980, Loavenbruck and Madell, 1981, Brooks, 1984? Tucker and Nolan, 1984, 1987 are as follows:

1. Organise the clinic so that the equipment is laid out nearly on the work bench.
2. There is a common 'core' of useful equipment required regardless of which technique is employed. A good auriscope is vital so that the ear canal canbe thoroughly examined. Visualization permits the observer to assess the condition of the

earcanal. Ideally, this should be clean and unobstructed. If a foreign body/cerumen is present, this ought to be removed prior to taking an impression. Presence of discharge requires ENT examination, a procedure recommended also when there is an indication for tympanic membrane perforation. Examination of the earcanal is also necessary to enaable the examiner to see if there are any sudden bends, projections (such as exostoses) or constrictions and variations in ear canal shape (hourglass or 's' shaped).

3. If the patient has a great deal of hair, it may be useful to use an ear cuff to keep the hair out of the impression. An ear cuff is a circle of paper cut to fit over the pinna. Fig.( ).
4. Canal tamping is the next step. An earlight or light-pen is desirable for inserting the tamp. A selection of ready prepared tamps in either expanded foam or cotton wool with a few inches of thread attached should be used. The commercially available expanded foam tamps come in various sizes, and these often require trimming to fit a child's ears. If making your own plug, examine the ear for the size and make a cotton ball that will comfortably fit the canal.

Requirement for tamping - In an untamped canal, the impression material, as it flows down the acoustic meatus, tends to depart from the sides and adopt a conical form, which gives little indication of the true direction of the canal. When a tamp is inserted, the material flows against this and spreads, thus making a much better seal and giving a much clearer indication of the direction and shape of the ear canal (Fig.54A). Earmolds made from an impression backed up by a cotton ball can decrease sound leakage by 15-20 dB over an earmold made without cotton. (Hoffman, 1964).

The ideal position for the tamp is just beyond the boundary of the cartilagenous and bony section of the meatus (Fig.54D). Thus, when the impression is removed and trimmed, it will just fall short of reaching the bony portion of the canal and will not produce discomfort or pain on mandibular movement. Use of plug also reduces the possibility of leaving debris in the ear. Fig. (55) Comparison between syringed tamp impression and a manually invested impression.

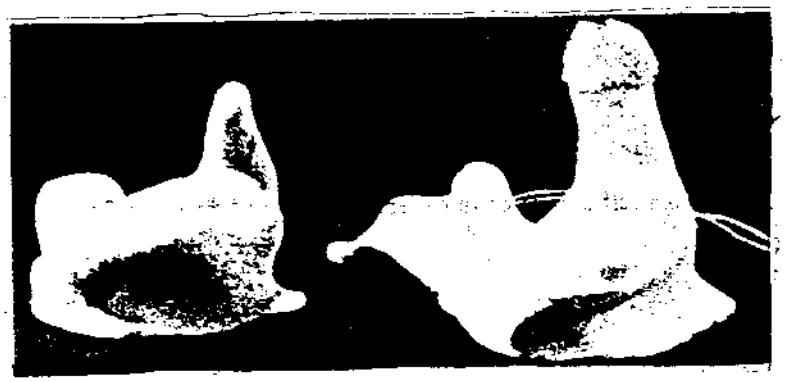


FIG. 55. COMPARISON OF SYRINGED TAMP & MANUALLY INVESTED TAMP.

5. Mix the impression material. Measure the liquid and the powder according to the manufactuer's specifications and

pour them into a beaker (when the weather is humid, it may be necessary to use less liquid) Mix with a spatula until the material is well combined. It should not be drippy but should flow easily. Excessive whipping of material is contraindicated owing to formation of airbubles which can cause shrinkage in final product (Hoffman, 1964).

6. Pour the material into the syringe. If manual method is used (not recommended), material is formed into a sausage shape and fed into the ear and pressed up.
7. Push down the plunger of the syringe until the material begins to emerge from the tip of the syringe (Fig.54f) .
8. Put synringe tip in the ear canal. Push plunger in, filling the canal completely upto the cotton block (Fig.54G).
9. Withdraw the synringe and fill the pinna, taking care to fill the concha and helix (Fig.54H).
10. Allow the impression to set according to the manufacturer's specifications (usually about 5 minutes).
11. Remove the impression. Pull pinna away from impression all around and then lift out the impression (Fig 54I). If the cotton block does not come out with the impression, gull the string to remove it.

The impression should be eased gently out of the concha and slowly withdrawn. Too rapid removal of a well-fitting impression can cause discomfort and even damage to the tympanic membrane due to the suction created.

If the impression material employed shrinks significantly in the cared proceaa or if there are minor flaws in the surface of the impreasion, it is worthwhile to apply a 'wash' coating. The hardened impression is first core bored and a piece of plastic tubing is then carefully pushed through to the end of the meatal portion. A small amount of less visions but chemically compatible impression material is prepared and coated onto the meatal section of the now hardened initial impreasion. This is then carefully and accurately re-inserted into the canal. When the wash has cured, the impression is removed and examined. If there is any indication that the mold has failed to reseat perfectly, it should be scrapped and a new impression taken (Brook, 1984).

12. Using an otoscope, check the ear for any residual impression material or irritation.

Fia.54A: Inspection of ear.

Fig.54B: Ear with ear cuff.

Fi9.54C: Inserting the cotton plug

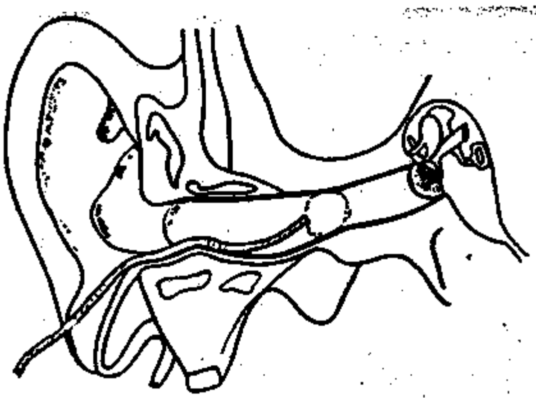


Fig .54 D: Cotton plug in canal.

FiG.54E: Filling syringe with impression material

Fig.54F: Inserting syringe into ear canal

Fig.54G: Filling the pinna with impression material

Fig.54H: Filling the pinna with impression material.

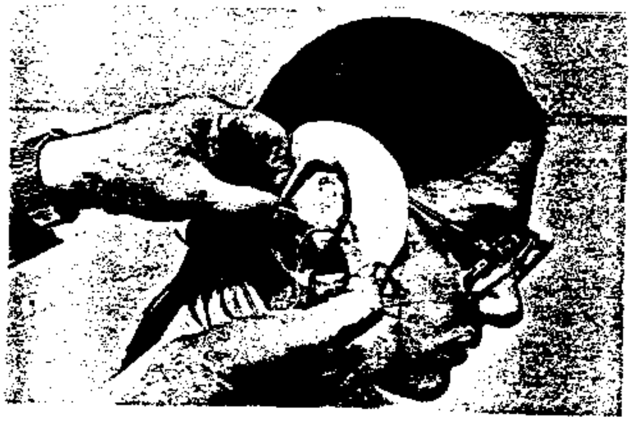
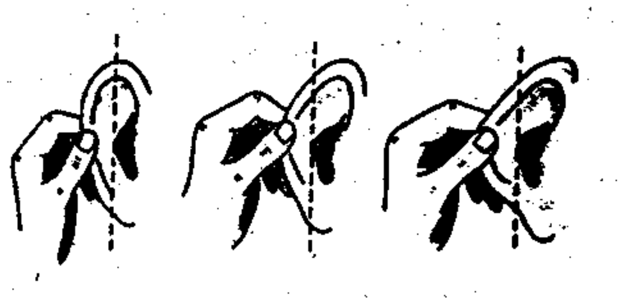


Fig.54I: Removing the impression.

Fig.54 J : Removing the impression.

Handling and packaging:

The impression should be posted for processing into an earmold within 48 hours (sooner if possible). Delay in mailing can cause shrinkage, with a resultant ill-fitting mold. Make sure to enclose information on the type of mold* material, colour tint, venting required, patient's ear and hearing loss. If there are any unusual markings in the ear, or if the ear is unusually soft (as in infant's ear), include this information with the earmold. Fig.No.54K shows different ear textures.



Fiq54K: Types of ear textures.

Packaging: To mail the impression to the earmold laboratory, a rigid box should be employed, large enough to contain the impression without deformation. The impression should be glued down to the base of the box or affixed by a large pin through the box, so that the meatal portion does not make contact with either the walls or lid of the box. No other packing material should be placed round the impression.

Consideration for special impression techniques:

An ear impression replicates the external ear contours, but the final mold may differ from the initial impression owing to a number of factors classified into (i) Deliberate factors, and (ii) non-deliberate factors (Nolan, 1985).

The most obvious deliberate factor is the modifications of the impression done at the earmold laboratory. The non-deliberate factors include the usage of dimensionally unstable impression material or use of an improper impression material incapable of providing accurate results. Uge of this highly accurate, very dimensionally stable impression material and technique would eliminate the nondeliberate factors. Polyether rubber impression brings about a substantial reduction in the number of remakes necessary to obtain a good acoustic seal (Madell and Gendel, 1984), especially for the high powered postauricular aids.

Fifield, Eamshaw and smither (1980) at the National Acoustic Laboratory, Sydney, in cooperation with the Department of Prosthetic Laboratory, developed a technique of using dental impression techniques and materials and impedance brdige to test the acoustic seal. This three- staged procedure involve)

Stage-1: The primary impression:

1. A cotton block is inserted into the canal.
2. A 6 em (2-inch) length of rubber tubing (PVC or silicone rubber) with an ID of 2 mm (0.076 inches) is guided on to the thread and pushed down to the cotton and secured so that

it will not move up the cotton when impression material is introduced.

3. A heavy bodied dental silicone rubber impression material is then mixed and syringed into the canal and concha to give An impression. (The tubing should be embedded into the impression).

<u>Stage-2</u> - <u>Canal build up</u> :

4. The impression is removed, and a coating of a medium - bodied (less thin) silicone material is applied to the surface of the impression from the end of the earcanal to just outside the entrance of the canal.

5. The impression is reinserted into the ear before the material has begun to set. Gentle pressure is applied for a short time to the outside of the impression to assist in the appropriate shaping.

6. Testing acoustic seal - at this point it is necessary to test the seal of the impression for which ,the impression is placed into the ear, and the tubing protruding from the impression is attached to the air pump of an impedance bridge.

7. The pressure is gradually increased to a maximum of 200 mm H_2o. The seal must be maintained for 5 seconds. If there is no loss of pressure, the seal is considered satisfactory. Otherwise earmold needs further build up. The seal should be tested after each build up until an adequate seal is

obtained. Patient is asked to open and close his jaw several times during the testing of the seal.

8. **Stage-3 - Applying a wash** - Once the seal has been obtained, the final'wash' has to be applied. A cotton block is re-inserted, and the thread is passed through the tubing in the impression. A thin - bodied silicone material is syringed into the ear canal and over the surface of the concha. The impression is then pushed down the thread and gently reinserted into the ear before the material hardens.
9. When the material has set, the earmold may be removed and the canal impression trimmed to the desired length.
10. The earmold laboratory must be instructed not to build up or modify the impression in any way during earmold fabrication. The laboratory should also be instructed to use thick-walled tubing to reduce feedback.

The three-stage impression technique is suitable for manufacturing all styles of earmolds and with all types of earmold material. Also, lather than making a new impression each time a young child needs a new earmold, the original impression may be modified. This was reported to the clinically useful for high gain post auricular instruments.

Because the material used is of a different texture, than that normally used, extra time and effort is required when using this technique. Once the skill is acquired, it takes between 35-45 minutes; also it is possible to work on both ears alternately so that two impressions for the patient can be produced in approximately 60 minutes.

The material is not as soft as the standard earmold impression material and does not come out of the ear as easily. The problem of debris remaining in the ear is one of some concern when using this procedure.

New ear impression technique for custom ITEs:

Orton, 1984 recommended technique for both taking impressions for canal aids and for FB5 application (a third generation soft build up material that can be added directly to the loose ITE and then inserted directly into the patient's ear for curing (about 20 minutes). The steps include -

1. Have the patient rest his head on a pillow with the ear that is to have the impression facing upward (instead of having him sitting erect).
2. Have the patient lightly clench a tongue depressor between the teeth or have him sit quietly and not talk.
3. Insert either impression material or coated aid into the ear and wait for the prescribed time until cured.
4. When the material is cured, remove and trim the excess.

Earmold for geriatrics with visual and dexterity problems:

This mold for this population deviced by Navarro (1976), is fabricated from an instant mold material. This material can be cut and drilled without commercial processing.

Procedure adopted:

1. The impression material is injected (after cotton-block insertion) into the earcanal and concha in the usual manner through a standard 30 cc syringe. A full ear impression is made.
2. Prior to setting of the impression material, it is pinched, causing a slight build up of material with inferior and superior concavity in the area where the handle is to be made.
3. After the impression is set, a mark is made at the level of the ear canal to indicate where the hearing aid tube is to be inserted.
4. The earmold is then cut down and buffed with a small hand drill to eliminate the extra impression material and the rough edges to fashion the handle.
5. After the hole for the tubing has been drilled and the earmold has been treated according to the manufacturer's direction, the tubing is Inserted.

The handle should protrude from the concha but should not extend beyond the lateral margin of the pinna and it should not interfere with placement of the tubing. Typical physical dimensions of the handle are approximately 1 cm wide, by 5 mm high with a slight concavity to allow firmer grasp .

The ear impression material:

The function of the ear Impression material is to accurately record the dimensions and spatial relationship, of the constituent parts of the external ear (Loavenbrack, 1981). If an ear impression material is to be acceptable for clinical use, it must satisfy a number of requirements as listed out by Loavenbruck and Madell, 1981.

1. It should have appropriate viscosity required to accurately register the detailed contours of the ear.
2. It should posses dimensional stability and retain its shape from the time of removal from the patient's ear until its processing.
3. Material should be nontoxic and non-irritant.
4. Should have sufficient elasticity when set to facilitate removal from the ear.
5. Should be relatively easy to use.

Additional properties listed out by Brooks, 1984 - include :

6. It must set in a reasonable time without undesirable side effects (eg. no exotherm).
7. It must have sufficient mechanical strength not to tear or permanently deform upon removal.
8. It must be compatible with dye and cast? materials for investment.
9. It must not be too expensive.

Types of impression materials -

Currently, a variety of earmold impression materials are available, having enhanced properties in relation to their predecessors (wax or plaster) These include as listed by Loavenbruck and Madell (1981), Brook (1984), Madell and Gendel (1984), Nolan (1985);

1. Viscous gels composed of a powder, and a liquid that are mixed together. This is no longer in common use.
2. Functional impression material are primarily dental impression materials like alginate. Owing to the poor dimensional stability over time (shrinkage) and relative weakness to tearing upon removal from the ear, it is unsuitable for audiological application.
3. **Soft cold - set acrylics** - Composed of a polymer and a monomer blend together. They are easy to use and set very quickly. They contain great deal of oil, facilitating removal of the impression, but this tends to make them dimensonally unstable. Example - Trumold, Aualin.
4. **Hard, cold - set acrylics** - They are exothermix when hardening, hence not recommended for impressions. They can, however be used for make repairs onthe acrylic molds.
5. **Condensation silicone** (Audiological silicone material) - these are composed of a soft base material and a hardener which are blend together. They are easy to mix, but temperature sensitive* hence should be mixed with a spatula since kneading by hand reduces the setting time; can easily be syringed into place. However, in common with all silicones, tearing of thin sections of material is always a possibility. It is dimensionally unstable, with a linear shrinkage of the order of 0.5% over 48 hours (Nolan, 1985). The predominant factor is that the material cures, as the name implies, by a condensation polymerisation reaction with an evolution of

volatile alcoholic by-products. Furthermore, distortion occurs if the material is stressed at any time, eg.Despite the drawback of slight shrinkage, this material does possess many of the other requisites, hence it is extensively utilized in theear impression work today. Commercially available brands include Audisil, Otoform (West Germany) and XL-80 (Westone).

6. **Addition silicones** (dental silicone materials). These have superb dimensional stability and are a considerable improvement in this respect over their condensation counterparts. It is capable of producing precise impressions which retain their accuracy over time and is therefore the optimal material today. These are available in varying viscosities and is composed of a base material and hardener containing to no oil. It is expensive and may be difficult to use with a standard earmold syringe. National Acoustics Laboratory, Sydney, has developed a special syringe for use with this agent and polyether rubber impression material. Commercial dental syringes may also be used by modifying the syringe tip. Commercial brands include Reprosil and Permagum, Reprosilputty 1500.

In a study by Nolan (1985), comparative properties were determined for the commonly used impression materials including dimensional stability, weight change on storage, viscosity, syringing characteristics, energy required to tear the material and the stress relaxation characteristics. Superb dimensional stability of the addition - cured silicones showing no significant shrinkage over time was the major finding. Major application was reported to be in provision of eanaolds for children wherein difficulties with the use of condensation silicones have been reported (Fifield et al, 1980) and for adults where high gain performance is required. Both these materials (condensation and addition silicones) are available in a number of consistencies - light, medium, heavy body and putty, putty is the best for audiological use. If a wash technique is to be applied, as may occur ocassionally when condensation materials are used, then putty and light-body consistency should be employed. However, care ought to be exercised when using this technique as distortion of the ear may otherwise occur.

7. **Polyether rubber dental impression -** This is composed of a base material and hardener, is highly accurate and very dimensionally stable. This material is commercially available as Impregum.

In the present section, the importance of good impression, by the use of appropriate material and technique by a skilled technician have been emphasized. With the earmold difficulties resulting from poor impression the above again further importance. The most common difficulties include as reported by Loavenbruck and Madell, 1981.

i) Insufficient canal length with a resultant feedback and hence a reduction in usable amplification.

ii) Earmold made without (or with insufficient) cotton packing may result in poorly defined canal portion of the mold, a loose fit and hence acoustic feedback or an uncomfortable fit. It can also result in an earmold that does not direct sound towards tympanic membrane and can cause a possible sound block.

iii) If helix is not sufficiently filled there may be difficulties With retention of the mold.

iv) Insufficient filling of the tragus may result in irritation caused by the receiver or with an ear level aid caused by the tubing rubbing on the tragus.

v) Earmold problems can also result if the earcanal is of an unusual shape Fig. shows an hour glass - shaped ear canal. Hardening of impression in the large central cavity with difficulty in removal may necessitate medical attention.

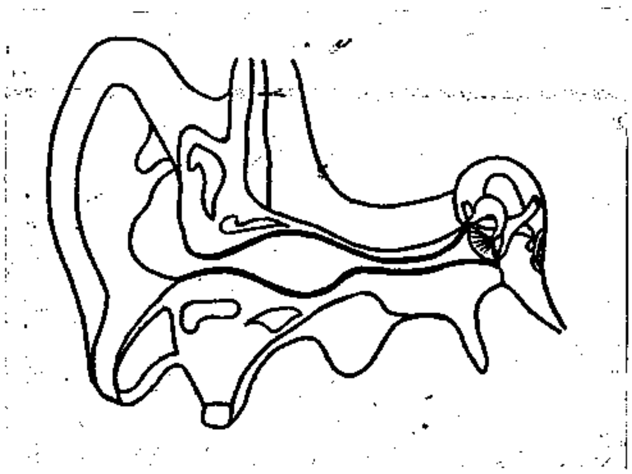


Fig.56 : Hourglass-shaped ear canal.

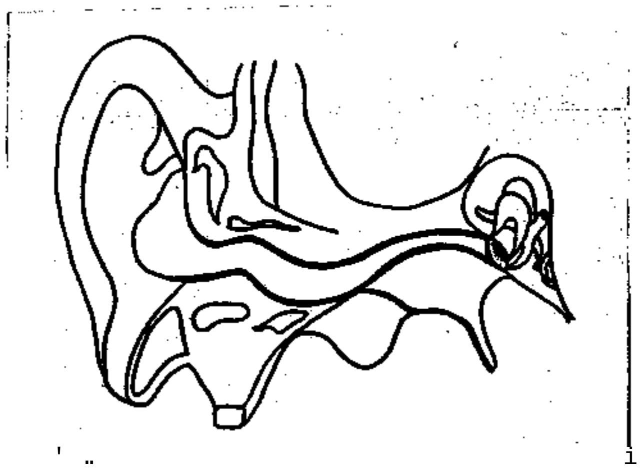


Fig.57 : 's' Shaped ear canal.

The 'S' shaped canal also requires extreme caution in making impression. Medical assistance may be sought if removal of the material is difficult. These two emphasize the necessity of careful aural examination prior to making the impression.

Processing the earmold:

Fabrication of the earmold falls subsequent to impression making following the above technique. This involves the following stages as outlined by Alpiner (1982), Nolan and Tucker (1984) and others:

1. Choice of material - testing for allergic reaction
2. Flasking
3. Packing with mold material
4. Curing
5. Trimming and polishing.

Earmold material - In fabricating an earmold, several different options of materials are available. The materials include hard acrylic, flexible acrylic, polyvinyl chloride (PVC), silicone and polyethylene (Caine, 1934; Lybarger, 1978).

Lybarger (1958) and Langford (1975) reported that sound transmission through the earmold is not significantly affected by different mold materials, i.e. it is acoustically insignificant. Hence the vital factors in material selection for fabrication of the mold as listed out by Leavitt, 1981 cited by Hodgson and Skinner (1981) include -

i) Patient's age

ii) Allergic considerations

iii) Need for a tight seal

iv) Need for durability and

v) Patient preference.

Intrinsic properties of a good mold material:

A material, to be used successfully should confirm with eertain criteria (Nolan, 1982, Loavenbruck, and Madell, 1984) -

i) Patient should be issued with the mold in one visit,

ii) Material should have dimensional stability, mold being a faithful replica of the ear contour with no shrinkage, no problem with plaster casting and no change of shape during processing.

iii) Overall cost of the material should be less.

Apart from the above criteria listed Blumer (1973) points cut -

iv) Material should be nontoxic

v) Should be relatively easy to use

vi) and above all provide physical comfort to the patient.

Materials in current use:As listed out by Leavitt (1981), these include -

1. Hard acrylic - most commonly used (Lybarger, 1978). Although

usually clear, it can be tinted to a flesh tone or coloured for cosmetic purposes. Because it is highly nonporous, it can be buffed to a very smooth finish for maximum user comfort. Hard acrylic offers the greatest durability of all current materials, and is generally nonallergenic.

2. **Flexible acrylic** - This is used for comfort and safety reasons, or when a very tight seal is required. As a general rule, children should be fitted with a soft earmold material so as to avoid injury to child's aided ear. Owing to the expansion of this material due to body's heat, a tighter seal can be achieved.

3. **Polyvinyl chloride(PVC)** - Used in the manufacture of earmold tubing, and soft earmold material for permanent earmolds. This material is sefter than flexible lucite and may be more durable than other soft materials.

4. **Silicone** - This is flexible, inert rubber material. Owing to its softness, it is used with very young children. Instant molds or swim molds made of silicone are also marketed. Lybarger (1978) has pointed out that when the silicone instant earmold is used, tubing attachment and replacement can be a problem. Additionally, silicone molds are less durable than the hard acrylic which does not pose any problem for children who require replacement every 3-6 month until about 5 years, and then approximately one replacement each year from the age of 5 to 9 (Northern and Downs, 1978). With adults, however, this consideration becomes very important.

5. **Polyethylene** - It is a semihard, waxy material which is used only in very rare cases of extreme allergy. This is the least

durable of all the earmold materials currently available.

6. **Combination earmolds** - These are made of two different materials. A hard acrylic outer portion can be used for durability and cosmetic appeal, while the canal can be made of silicone or flexible acrylic for maximum comfort when a tight canal fit is needed.

Table summarizes the earmold materials (Lybarger, 1984, cited by Katz, 1985).

Problems related to the technical usage of earmold materials:-

1. Inconsistency in the setting time of materials owing to variation of room temperature (colder the room, longer is the setting time). For cold cure acrylic, a room temperature of approximately 70^{0}F (21^{0}c) was found to be most satiafactory (Blumer, 1973).
2. Further problems relate to the technician using the material with the complaint of fumes from the liquid monomer and excessive dryness of skin when handling the material. A good extractions system in the room is the solution to this problem and either surgical gloves or a good barrier cream provides the answer to the second problem.
3. Allergy with red, sore and inflammed ear is the problem with the patients, with the main cause being roughness of the surface for which varnish helps. But varnish does not adhere to the mold surface perfectly, with a tendency to crack or a film of varnish detaching and curling out at the edges, thus

Table 13 : Earmo)ld materials

Material 1.	Hardness 2 .	Color 3.	Surface 4.	Tubing attachment 5.	Remarks 6.
Acrylic (Lucite)	Hard	Clear, pink tint, opaque flesh/brown.	Highly polished	Cements easily	Most commonly used. comfortable, durable, easily cleaned.
Special acrylic (Super Alerite)	Hard	Clear, pink	Highly polished	Cements easily	Useful in most cases when allergy is a problem.
VinyKPolyethyl methacrylate)	Soft	Clear, opaque flesh	Smooth	Cements well	Tends to softea with body temperature; comfortable.
Acrylic body vinyl canal	Body hard, canal soft	Clear, opaque flesh	Body polished canal smooth	Cements easily	Good acoustic seal with comfort.
Special acrylic body vinyl canal	Body hard. canal soft	Clear, opaque flesh	Body polished, carnal smooth	Cements easily	Non-allergic if special vinyl material used.
Vinyl (Thermoplastic)	Soft	Opaque, flesh or brown	Smooth	Cements well	Good for children's molds, also in translucent tint or brown.
Silicone	Medium soft	Clear, pink. opaque, flesh brown.	Smooth	Mechanical attachment used.	Useful where allergy is a problem
Polyethylene	Moderately soft to some what hard.	Somewhat cloudy to clear	Fairly smooth	Mechanical attachment used	For severe allergy

producing a rougher surface and increased irritation. A solution to this problem as reported by Blumer (1973) for cold cure acrylic mold is to dip (after hardening) into pure chloroform (a solvent for cured acrylic) for no more than 30 seconds which produces minimal dimensional change, with considerable improvement in the surface smootheness of the product.

2. **Testing for earmold material**: As suggested by Alpiner (1982), the possibility of allergic reaction to the mold material ought to be ruled out prior to fabricating the mold. This involves taping of a disc of the earmold material to the inside of the user's arm for 24 hours and watching out for the typical allergic signs.

3. **Flasking**: This involves plaster preparation in a rubber bowl- a mixture of plaster of paris and water. Apply a thin coat of this over the impression material. Place the impression inside the flask aad put the plaster little by little. Use pressure to avoid air bubbles. As reported by Nolan (1985), the improved production procedure incorporates the use of vacuum injection apparatus for plaster mixing, as a routine - eg. whip-mix which avoids the problem of blow holes and other surface blemishness on the earmold. Once the plaster is set, impression is removed carefully.

4. **Packing with the mold material** - A separating medium is added to the plaster cast. Required amount of the polymer and monomer in generally 2:1 by weight is blend and placed in

the plaster cast. By increasing the pressure in the clamp, the excess material is removed. If material remains unreleased, addition of the material is dictated. This pressure should be maintained until curing is over.

5. **Curing** - The flask is cured for two hours in the oven at 100^{0}c, or is immersed in cold water and bringing it gradually to boil for not less than 30 minutes. The cured material is allowed to cool.

6. **Trimming and polishing** - The cured flask is trimmed with sand paper disc in dental lathe and made smooth and of appropriate thickness. Sound bore is drilled, and other modification like venting of appropriate length, angle and diameter to bring about necessary acoustic modifications are introduced.

7. Earmold is then polished using cotton brush and pumice powder in the dental lathe. Lock ring is subsequently fitted using cold cure acrylic on the backplate. Nolan (1985) reports that it is advisable to use nylon rather than metal lock rings as they avoid the earphone nub being worn away, which can result in acoustic feedback problems and finally falling off of the receiver from theearmold.

Prior to giving the mold to the patient a check for fitting of the receiver and of the amplification system on the subject's ears in toto is imperative.

The silicone rubber molds require more skill in manufacture and are difficult to fabricate into solid and shell format. The procedure involved in the fabrication of silicone mold reported by Nolan and Tucker (1984) follows a process of 'zero interaction' with the mold once it is removed from the plaster cast. The process may be simplified by omission of the steps facilitating 'built in' sound tube and lack spring This work can be carried out after the cured mold has been removed from the plaster. However, the sound tube may,over a period of time close up and eventually become occluded, the resultant of both the materials being dffficult to drill, the like being true with vinyl molds.

Processing of pourable silicone elastomer:

Dow Corning MDX44210.

i) Prepare plaster - de-air

ii) Make plaster model

iii) Wire sound tube through model using stainless steel or copper. Silicone tubing for sound tube covers wire seal plaster.

iv) Mix elastomer plus curing agent.

v) Add medical fluid for better consistency

vi) De-air silicone mix.

vii) Pour silicone into plaster model

viii) Cure at l00c for 15 minutes in warm air oven,

ix) Remove and check

x) fit.

Note: a) The procedure is implicated tor post-aural aids only,

b) No specialised equipment is required.

Processing of composite mold: Molloplast - B silicone denture soft-lining material with acrylic back-plate.

i) Prepare plaster - de-air

ii) Make plaster model

iii) Wire sound tube

iv) Wax up for lock spring (Pocket aid only)

v) Place in dental flask

vi) Separate flask - boil off wax.

vii) Pack in silicone, press up

viii) Paint on bonding agent (Primo)

ix) put on acrylic back plate,

x) Press up

xi) Cure for 2 hours at 100^0c in water bath

xii) Remove and check.

Summarizing, the hearing health, professional is answerable to the ears-its acoustic and physical comfort. For the baring impaired, the role of earmold is not to be lightly dismissed or ignored owing to reduction in efficiency of the habilitative or rehabilitative programme. The present section has highlighted the fact that A good beginning makes a good ending,implying an appropriate choice of material, a good impression, employing a good technique employed by a skilled technician (the good beginn- ing) ensures a good fitting (acoustically and physically) mold ... and alls well that fits well.

CHAPTER-7

MAINTENANCE AND REPAIR OF EARMOLDS

Care and maintenance of earmold are vital for an optimal fitting of the hearing aid. Here, the problems commonly encountered,pertinent to the earmold, their captation and remediation have been discussed inlieu of the current techniques employed.

The problems include -

1. No putput from the hearing aid
2. Low putput or distorted sound
3. Squeal produced owing to the acoustic feedback present at useful volume control setting.
4. Background noise problems
5. Pain or abrasion of external ear owing to ill-fitting mold
6. Hinderance with jaw movement etc. (Riedner, 1978. Orton, 1981).

These can be identified by visual inspection and listening checks. Majority of these problems, pertinent to the sound channelization to the ear and their rectification, of removal of cerumen/debris has received vast and varied attention.

In a report on bacteriology and cleaning methods of stock earmolds, an attempt was made to identify by visual inspection and isolate the bacterial population by Lankford and Behnke, 1973. Results indicated that neither staphylococcus aureus not Escherichia coli were identified contrary to Talbott's study (cited by Lan) ford, tad Behnke, 1973) wherein four bacteria (Staphylococcus epidermidis -pink or puvple, Micrococcus spp. Streptococcus spp. Bacillus spp) and no fungus were identified. Here the quantity of bacteria isolated was minimal, and there was no relationship between the amount or type of bacteria identified and the mold material (acrylic or vinyl) and also the facility from which the sample was taken speculations regarding this findings included -

1) Since all cleaning solutions in use could be classified as having either bacterioatatie or bactericidal properties, the cleaning methods were probably adequate in reducing bacteria or effectively impeding its growth.
2) The composition of the earmold material was unsuitable for sustaining bacterial growth.
3) Owing to otologic examination prior to hearing aid evaluation the possibility of client with otitis externa or madia were substantially reduced, thereby reducing the number of available pathogenic microorganisms being transferred to the mold.

The earmold cleansing procedures adopted included the following -

1. Pipe - stem cleaners
2. Soaking and washing in a mild concentration (1:750) of Zephiran chloride (Winthrop laboratories)
3. Washing with mild liquid soap and water
4. Soaking and washing in cetylcide (Scientific plastics)
5. Soaking and washing in an ultrasonic cleaner employing an earmold cleaning solution (Hal-Hen Co.)
6. Washing with isoprophyl alcohol (70%) solution

Adopting cleansing method:

The above are the techniques commonly employed, of which alcohol as a cleansing agent is not considered suitable, leading to cracking or etching of the mold. In determining the cleansing method to be adopted, cost is a factory the least expensive being mild soap and water and the most expensive being ultrasonic cleaner.

As reported by Loavenbruck and Madell, 1981, depending on the amount of wax accumulated, cleaning is necessitated 1-3 times a weak. Drying of the molds is a must prior to re-attaching the receiver. This is best accomplished if the mold is washed at night and not reattached until the following morning.

It can also be greatly assisted by the use of an earmold blower.

Lankford and Behnkesl973, cleansing procedure:

1. Place the dirty earmold into a bacterio-static or bacterio-cidal solution.
2. Perform earmold cleaning on a sehedule basis (for instance after each evaluation, at the end of each work day, or once each week). The cleaning schedule depends onthe demand for certain sizes, types of stock earmolds or the number of clients seen each day.
3. If necessery, manually wash the earmolds, even though an ultrasonic cleaner is employed.
4. Thoroughly rinse the earmolds with water following the washing procedures.

5. Dry each earmold before It is reused. Compressed air is useful in blowing water droplets from the tubing and canal of the earmold.
6. Place the cleaned earmold in a container labeled appropriately so that there is no possibility of confusion with other containers holding dirty earmolds.

Use of ultrasonic cleaners:

This is used for sterilizing earmolds and impedance probes. Hal-Han Co.lnc, Long Island City, New York outlines the procedure for earmold cleaning employing this method.

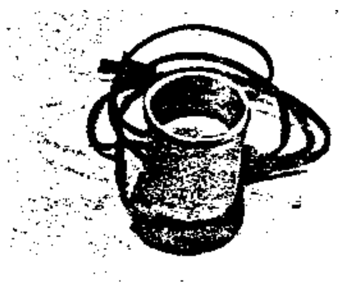


Fig. 58: Ultrasonic cleaner.

Earmolds ought to be cleaned individually. The only time when two earmolds should be placed in the same beaker is when an individual uses two hearing instruments and earmolds are from the same individual.

The ultrasonic cleaner, should have a carrying solution consisting of the actual solution used to clean the mold inside the main tank (approximately one inch of solution). This solution is used to transmit the ultrasonic frequency through the unit and into the earmold which should be inserted in its own beaker.

The earmold is placed into a small glass beaker and enough cleaning solution poured into the beaker to cover the entire mold. The beaker is then placed inside the ultrasonic cleaner. Same instructions should be followed for each additional earmold to be cleaned. Some ultrasonic cleaners hold from three to six individual earmolds in this manner. Tarn on the ultrasonic cleaser for approximately 4-5 minutes, then remove the beakers from the machine and pick up the mold with a tweezer. Hold the mold under a running faucet for a second to wash away the solution, wipe dry and blow out the opening with an air blower.

Drying the earmold:

1. Use of forced-air earmold cleaner: This is used to remove moisture from earmold and tubing after they have been cleaned. This is also helpful in determining the presence of an obstacle to the passage of sound through the earmold(Loavenbruc) 1981.)
2. Pipe cleaners - Used to dry out the sound bore after washing, apart from being used to remove wax/debris from the mold.

The above suggestions for earmold cleansing, reflected from a review of literature are mainly for hearing aid dispensers and audiologists conducting hearing aid evaluations, but most of them ought to be communicated to the client wearing the hearing aid.

The other aspects of earmold problems pertinent to the different types of hearing aids is discussed in the following pages: comprising of the modifications in the earmolds, that can be accomplished at the dispenser's office Without dispatching it to the laboratories.

Guidelines for cafe of the earmold:

1. Guard against loss, breakage, heat, pests and chemicals that react with the aarmold materials.
2. Caution your child against inserting foreign material (mud/stick etc) into the mold.
3. Passage of earmold canal should be kept free of dust, ear wag/debris etc. - detach the mold from the receiver and clean periodically with mild detergent and lukewarm water or any other means like pipe cleaner etc. Refrain from using hot water for cleansing owing to the resultant warpage of the mold. Wipe dry and refit the receiver.
4. If loose or cracked, replace it. This is of greater importance to geriatric and paediatric population.
5. Receiver should fit into earmold without revolving. If so, ring of the mold ought to be fixed.
6. When connecting the mold to the receiver, volume control should be turned down.
7. Presence of wax or discharge requires attention from an otologi
8. If irritation occurs with the use of earmold, contact the earmold technician for proper adjustments and/or the use of nonallergenic mold.
9. Use ear tips till the mold is ready.

Table 14: TROUBLE SHOOTING BODY LEVEL HEARING AIDS - PROBLEMS PERTINENT TO EARMOLDS.

Problem	Possible cause(s)	Remediation
l.No output from the aid.	Mold blocked with wax/ debris.	Unblock with a wire or soft tooth brush. Any of the methods discussed above may be employed.
2.Low output or distorted wound	Mold partly blocked.	Unblock the mold.
3.Aid whistles when worn(squeal due to acoustic feedback)	i)Mold bad fit. This is especially true for children.	New mold required. The following table gives average months per set of earmolds for children whose molds were replaced at the first evidence of feedback difficulty(Northem and Downs, 1978).
	ii)Mold inserted in-correctly.	Refit mold
	iii)Wearer's hair in ear with mold.	Remove hair, refit mold

Degree of loss	Average months per mold	
	21/2 year old child(N-25)	21/2 year to 5 year old child (N-27)
Mild(30-55 dB)	3.0	5.2
Moderate(56-75 dB)	2.7	4.1
Severe (76-90 dB)	2.5	5.6
Profound (91-110 dB)	2.0	4.6

1.	2.	3.
	iv)Bush(metal) ring) loose in mold.	New mold/repair required.
	v)Bush worn out receiver ill-fitting.	New mold or bush required.
	vi)High-necked garment pushing mold out of position (polo-necks)	Make sure that these are free from interference with ear and mold.

TROUBLE SHOOTING BTE AND EYEGLASS AIDS-PROBLEMS PERTINENT TO EARMOLDS

l.No output from the aid.	i)Mold blocked with wax.	Gently clear with wire and wash.
	ii)Tubing clogged	Replace or clean with pipe cleaner
	iii)Tubing flat	Replace
	iv)Condensation in earmold tubing.	Remove from earhook, blow out condensation using Forced-air earmold cleaner. Place in a packet of silica gel and a lock-tap plastic bag to remove the moisture. Use Dri-tube.
2.Low output and/or distorted sound.	i)Moldpear hook, tubing partly blocked.	Replace or remove the aid, clean with the given earwax removal tool only.
	ii)Tabe flat.kinked or twisted.	Replace
	iii)Earhook inco-rrect.	Replace

1.	2.	3.
3.Poor quality or distortion	i)Tubing too long	Shorten tubing length.
	ii)Earmold+ earhook or tubing partially clogged.	Replace, or remove from aid and clean.
	iii)Earmold canal too long(also hindering temporo-mandibular joint movement).	Shorten canal
	iv)Earmold needs venting.	Make vent.
	v)Barhook incorrect	Replace.
	vi)Wrong type of tubing.	Replace.
4.Noisy sound	Earhodk or tubing partially clogged.	Replace, or remove from aid and clean with ear wax removal tube or pipe line cleaner.
5.Excessive battery usage.	Earmold, earhook or tubing, partially clogged.	Replace or remove from aid and clean.
6.Aid whistles when wom-acoastic feedback.	i)Poor fitting mold	New mold required. Remake earmold using vinyl, unpolished material.
	ii)Wrong type of mold	Use vinyl, unpolished material; usually seen with high powered aids.
	iii)Earmold fitted incorrectly.	Refit
	iv)Wearer's hair in the ear with mold.	Remove hair,refit
	v) High necked garment pushing meld or aid out of position.	Make sure that the garment does not interfere with the aid.

1.	2.	3.
	vi) Earhook not fully screwed up for thread worn.	Screw tone hook to correct position.
	vii) Split in tubing or earhook.	Replace.
	viii)Wrong type of tubing(especially with high powered aids).	Some high power aids require double wall tubing? must be No.13 tubing, use of 680 or 1000 ohm earhook is recommended for this unit.
	ix)Earmold venting too large.	Replace the vent opening or eliminate.
	x)Tube hardened/loose	Replace.
7.Aid rubbing. causing sore ears.	Tubing too short or pushed onto elbow too for.	Adjust/replace length of tubing.

IN -OFFICE EARMOLD MODIFICATIONS FOR IN-THE-EAR HEARING AIDS (Orton, 1981)

I.Fit problems. 1.Soreness and discomfort.	i)Poor impression. il)Msnufaeturing process.	i) For custom ITE aids and earmolds, make good impression, canal and shell modification. ii) Remove excess material by grinding and polishing the offending area common problem areas are usually in the helix, canal and around the bottom and ridge around the concha. When making comfort adjustment. remove material on opposite areas of the aid since the mold may not be thick enough to allow to remove enough plastic in the area causing discomfort. When removing material on a higher gain aid, be careful not to remove too much or feedback may ensue. Caution: When removing material on a custom ITE, hold the instrument upto an incandescent light bulb(with battery drawer removed, if possible). Some portions allow more light to shine through Grind these thin areas. The helix area can usually be reduced substantially without any fear of creating a hole in the case. If disinclined to modify aid due to thin area, mark

1.	2.	3.
		the spot with a black grease pen in the area you want the factory to modify
2.Too tight a fit or cannot re-move aid from	i)Pressure points.	Look for areas where aid is too tight.Reduce tightness by grinding and buffing the area and the area opposite.
	ii)Problems with manual dexterity(lTE being easier to manipulate than BTE owing to the one-piece construction.	When the aid fits deeply into the concha, cutting removal notches into the helix and intertrigal incisure area of ITE aid will aid easy removal. Utilize the dentist drill with a small diameter drill bit and cut a 1/8" deep horizontal notch across the helix and/or the intertragal incisure area about 1/12" down the earmold from the face plate. Do not cut too deeply into the mold.
3.Mold too loose	i) Poor impressions ii) Manufacturing process.	Build up shell where locking capabilities will be improved. Soft build up products - Soft plastic sleeve*: (starkey FBI and FB2) can be easily placed over the canal of any type of earmold or in-the-ear healing aid. This snugging of the canal is effective in reducing or totally eliminating acoustic feedback Soft build up materials include: Adco Soft Add-On, Starkey FB3 and cushion Grip dental adhesive. Prior to the advent of the two aforementioned materials, cushion grip was used with good acoustic results: it is, however esthetically less desirable than the Adco due to its reddish orange tint and numerous small bubbles. The Starkey FB3 clear 'soft dip' procedure is useful when a thin coating of soft material needs to be added to the canal. One drawback is that it must cure 12 hoars before the user can insert it into the ear. Hard build up material include - Hard Adco Mold, Starkey FB4 and clear non-allergenic nail polish-when a small amount of build up is required this can be used quiet successfully.

1	2	3
4.Hole or crack in shell	i)Manufactaring defect. ii)A drop on a hard surface (physical damage)	Patching holes inthe aid or adding retention to the helix or canal being best accomplished with the FB4 hard build up* Patch up with polymer - monomer mix or other patching material.
5.Allergic reaction to shell material.	-	Coat earmold/shell with hypoallergenic nail polish. Remaking the shell with hypoallergenic lucite material may be required.
11.Sound quality problems.		
1.Barrel sound stuffed up: does not like sound of own voice.	Linked to an excess of low frequencies.	Reduce low frequencies by shortening the canal, enlarging the present vent (using SAV) or as a last resort, removing the entire vent area outside of the aid itself, or a combination of these modifications.
2.Background noise problem + too loud sound.	i)Over expectation from amplification ii)Upward spread of masking.	Counseling regarding a realistic expectation from amplification. Reduce low frequencies. An inbuilt characteristic of ITE aid is to give a better signal to noise ratio in noisy situations owing to the microphone placement and pinna effect which may improve the individual's subjective hearing abilities in noise. Since background noise is of low frequency. venting and shortening the canal offer the remedial measures.
III.Feedback problems.	Acoustic feedback occurs under the following conditions i)Looae mold ii)Vent is too large for the power required.	Leave the receiver tubing long (especially in IROS fitting. permitting delivery of the amplified sound closer to the tympanic membrane while the short canal reduces the 'stuffed up' or 'head in barrel' feeling, trim it to the desired length for both comfort and to reduce feedback. Whan feedback is due to the other problems, the dispenser has a veritable arsenal of 'build up' weapons available to try prior to sending the sending the aid back for a time consuming and/or expensive

1.	2.	3.
	iii)The canal la too short. iv)Canal is too long and butts up against the ear canal wall v)Excessive high frequent peaks. vi)Excessive mandlbular motion when smiling or chewing.	remake. Oiling the ear - to reduce minor feedback, lubricate the ITE and/or earmold. A light coating of Debrox or baby oil may be used. Petroleum based vaseline is not recommended owing to its heating up inthe ear canal.
3. Lack of clarity of speech signal.		Increasing high frequencies by bell shaped or stepped canal bore. After canal length reduction to appropriate length, belling is done. (1) Hold the hearing aid upto a light bulb to determine the amount of material remaining in the tip of the canal, (ii) If safe to proceed, remove the receiver tubing and recheck to be certain that the foam block is in place within the receiver tube and that the receiver tube itself is securely fastened to the canal wall. (iii) Use a round end burred bit on the dentist type drill to bell the canal to the proper dimensions. After this modification any rough spots should be buffed and polished. Vent too large - by placing a small to moderate amount of lambs wool or foam filter in the vent. feedback can successfully be eliminated without creating a blocked feeling, also increasing clarity.

CHAPTER-8

DECISIONS TO MAKE WHEN ORDERING THE MOLD.

Researcher's valiant effort to solve the 'mystry of the best fit' apart from solving innumerable problems, haa lead to an alarming confusion among the professional spectram. Here the key to this ancient puzzle may be found.

No two human beings are alike and no two ears are alike too. Thence the decisions to be made in mold fitting is purely custom designed to fit the physical and acoustic needs of the client.

Mynders (1986) gave a consolidated generic list divided into subcategories of the various earmold options available from a commercial ear mold dispenser. The list comprises of:

I. Physical style options.

a. Regular
b. shell
c. Canal shell
d. Skeleton
e. Semi-skeleton
f. Canal-lock
g. Canal lock with helix.
h. Canal.

II. Non-occluding options.

a. CROS (A, B, c)
b. Janssen
c. Free Field
d. Modified Free Field
e. Advance Design Free field or Universal non-occluding.

III. Anti-feedback options.

a. Power Mold
b. Tragus
c. Macrae Anti-feedback.

IV. Modular Hearing Aid Molds.

V. Acoustical Style options

1. Parallel vent
2. Diagonal vent
3. External vent
4. S.A.V.
5. P.V.V.
6. Custom vents
7. Short-canal/wide Bore
8. Belled Bore
9. Dural Diameter
10. Advanced Design Free Field
11. Killion 6R12
12. Killion 6AM
13. Killion 8CR
14. Killion 6B0
15. Killion 6B5
16. Killion 6B10
17. Killion 6C5
18. Killion CIO
19. Knowles Dampers
20. Killion 6EF
21. Libby Horn 6-EFA
22. Libby Horn 6EFB
23. Libby Horn 8CR
24. Libby Horn Free Field
25. C.F.A.# 2
26. C.F.A. # 3
27. C.F.A. # 4
28. C.F.A. - MC
29. C.F.A. # 5
30. Wide Range Mold
31. F.G.M.
32. Tubing sizes
33. Macrae Molds
34. Tube Fittings

VI. Material options.

a. Poly Methyl Methacrylate (Lucite)
b. Poly Methyl Methacrylate (non-toxic)
c. Poly Ethyl Methacrylate.
d. Thermoplastic polyvinyl chloride.
e. Non-toxic silicone.
f. Polyethelene
g. Combinations of some of the above.

In offering a consolidated option list, the fitter must return to the comprehensive list of earmold functions listed by Mynders(1986) -

1. To provide a satisfactory acoustic seal.
2. To couple the hearing aid to the ear acoustically, and to modify the acoustical signal.
3. To retain the hearing aid on the pinna.
4. To be comfortable to wear for an extended period of time.
5. To be aesthetically acceptable to the client.

The above can be articulated into four fundamental considerations.

1. Choice based on type and degree of hearing loss-hence the acoustic and material considerations.
2. Flexibility of ear canal, thence the material considerations.
3. Special considerations like colour tinting of the mold based on the age and cosmetic acceptability.
4. Other physical modifications for visual problems, digital dexterity problems as in geriatric population etc.

<u>Earmold selection based on degree and hearing loss configuration and the type of hearing aid to be prescribed:</u>

The type of earmold, the material to be utilized, length of the canal, type of venting suggested as an Initial choice of earmold as listed by Skinner (1988) is as follows:-

Table 15 : Suggested initial choice of earmold material, type and venting. The sound channel dimensions (tubing and sound bore) should be selected in conjunction with the frequency respense and gain of the hearing aid.

Degree of hearing loss	Hearing aid			
	Canal	In-the-ear	BTE, Eye glass	Body level
Mild	Hard acrylic, capillary vent.	Hard acrylic, capillary or 2-3 mm vent.	Hard acrylic, capillary or 2-3 mm vent, short canal, skeleton, regular thickness tubing.	Hard acrylic capillary vent, short canal snap ring.
Moderate	Hard acrylic, me vent.	Hard acrylic or soft canal, capillary vent medium canal	Hard acrylic, capillary vent, medium canal, skeleton, regular thickness tubing.	Hard acrylicno vent, medium canal, snap ring
Severe to Profound	—	—	Flexible acrylic, no vent, long canal, shell, thick tubing.	Flexible acrylic no vent, long canal, snap ring
Low frequency-normal MCLs; high frequency-moderate HTLs.		Hard acrylic 3 mm vent, short canal.	Hard acrylic 3 mm vent-with short canal or open earmold.	-

* If the prescribed real ear gain at 500 Hz is less than or same as that it is at 2000 Hz, a horn earmold is recommended Stepped-bore tubing, and/or tubing glued to a sound bore that has a large internal diameter (3-4 mm preferably) can be used with BTE or eyeglass aids. For body aids, the sound bore should be a constant 3 mm ID from the snapring to the tip (or belled to an even wider diameter at tip to pressure high frequency gain.
* If the prescribed real ear gain is less at 2000 Hz than at 500 Hz, the sound channel should have a smaller diameter to decrease the high frequency energy. For BTE and eyeglass aids, a constant diameter tubing that has an ID of 1.93 mm (% 13) to the tip of the earmold is recommended. For body aids, the sound bore Should have a constant diameter of approximately 1.5 - 1.9 mm. A reverse horn such as Killion' 6EF earmold with number 16 or number 19 can be used.

Other acoustic considerations:

Venting: This allows the low frequency sound to enter the ear unamplified, permitting a more natural sound quality and reduc ing the complaints of hearing"like being in/a tunnel". It has the additional effect of reducing the interference of low fre- quency background noise. (Loavenbruck and Madell, 198ly Brook, 1984; Lybarger, 1985, and others).

The effect of venting is subjective and depends on many variables including -

i) the vest diameter.

ii) the particular hearing aid.

iii) the setting of the aid.

iv) the input level

v) the length of the canal

vi) Placement of the vent

vii) the distance between the end of the mold and tympanic membrane etc.

It is hence preferable to procure an earmolds with adjustable vents and to try different vent sizes to demonstrate the best acoustic results.

Length of the canal:

The acoustic modification and normal physiology of the tamporo-mandibular joint are the criteria determining the length of the canal portion of the earmold. "...audiologist may want a long canal portion to the earmold (as when attempting to get a tight seal to avoid feedback with severe hearing losses). There is however a limit to the depth of the mold prior to interference with mandibular functioning. The rule of thumb is that the earmold should usually not go beyond the bony portion of the canal (about the first two thirds of the canal). However, in cases with very severe losses, it may be necessary to go beyond the bony portion in order to obtain the required power without feedback. You may begin with a long canal and shorter it if it becomes too uncomfortable for the patient" (Loavenbruck and Madell, 1981).

Flexibility of ear:

Knowledge of flexibility of the external ear permits a better manufacturing of the earmold in terms of reduction of acoustic feedback and aiding retention Lavenbruck and Madell (1981),report - "... softer the pinna, the fuller the earmold will have to be in order to avoid feedback", This information being useful for the paediatric population. If an ear is very 'hard', a less-full meld will provide more comfort. This, thence calls for the choice of the material.

Earmold material:

The choice of earmold material depends upon the degree of hearing loss, flexibility of the external ear and the acoustic modifications required. The most widely used material is lucite, a hard, nonporous plastic which is easy to insert and appropriate for venting. Polyvinyl chloride (PVC), another commonly used soft material has the advantages of earmolds being comfortable; ease of obtaining acoustic seal and hence recommended for patients with severe to profound losses. This can provide for venting, which, in the dispenser's office presents some difficulty, owing to the closing in of the bore. However, plastic inserts caa be successfully used to keep the vent open.

Hypoallergenic earmold materials like silicone is used for patients having allergic reaction to the commonly utilized material.

Age and Aesthetic acceptance - colour tinting:

"Although the plastics of which earmolds are made is colourless, most laboratories offer a variety of colour tints to meet the preference of the hearing aid user. The hard plastic molds are available clear or with a cloudy appearance. They may also be coloured dark brown to match patient's ear" or tinted with other colours to match the child's apparel. The soft earmolds are generally not available with a clear appearance, however, available in a pink or brown flesh tone." (Loavenbruck and Madell (1981).

All of the above information ought to be furnished when ordering the earmold (s). Format for earmold recommendation in a large dispensing unit as given by Loavenbruck and Madell, 1981, comprises of the following.

EARMOLD ORDER **Date**

NAME
ADDRESS
AUDIOLCGIST:

TYPE	MATERIAL
-—- Regular custom	—— Lucite - transparent
______Tnvisimold.	- opaque
______Hydamold.______	Skintex
— - semi-hydamold	— — Satin-Flex
—— Canal mold	— - Aural-flex
-—— Vented mold	---- Silicone
______Variable vented mold	______ PolySheet
—- Non-occluding mold	
-----S.A.V.	

Ear:______Right______— Left______—Binaural
Type of Loss:
Right — Mild — Moderate -- Severe — Profound
Type of hearing aid:
Ear level — Body — All in the ear -- Glass —
Make the model:
Comments:
Return to patient________Return to ——
Pick up earmold - — — cost -----

CHAPTER-9

EARMOLD IN HEARING AID SELECTION

Earmold is a vital component of every amplification system and the key to every successful fitting of the hearing aid lies in, apart from many ether factors, the appropriate selection of earmolds. As seen earlier, modification of physical dimensions of the earmold alters the hearing aid response. This effect on the listener's aided performance has not been customarily incorporated in a systematic way into most hearing aid evaluation procedures. Evaluation procedures attempting to distinguish between hearing aids or between different settings on a master hearing aid, on the basis of speech discrimination scores, etd. use the same occluding mold with each aid neglecting to assess an important interaction (McClellan, 1967). The present section attempts to highlight the following;.

1) Use of custom earmolds (against stock) during hearing aid selection
ii) The importance of choice of earmold with the modifications like venting in the choice of hearing aid
iii) Acoustic feedback and its control in selection and use of hearing aid.
iv) Alternate avenues when facilities for instant/custom earmold making are not available as for reducing acoustic feedback.

Custom vs stock earmolds:

Geetha and Malini (1985) in a study on seven adults and three children who were potential hearing aid candidates, evaluated the relative change in performance with hearing aid yielding best performance,using stock vs custom earmold. Stimuli used with adults were verbal, comprising of questions, common words/spondees and monosyllables presented at a distance of five feet. For children, conditioned responses were elicited using noise makers of various frequency spectra and speech at 5, 10, and 15 ft. distance without visual cues. Results indicated that four out of the seven adults demonstrated significant improvement in performance with custom molds with all the three types of speech materials used. Others demonstrated variability with the speech material used. The data on children was inadequate to arrive at any significant conclusion.

Of importance here, is the finding that the hearing aid yielding the best performance varied with the earmold used (stock versus custom made). Further, the gain of the hearing aid yielding maximum scores with custom earmold was lower than that of the aid selected with the stockearmold, the mean difference in the gain being 14 dB with a range of 4 to 27.7 dB

In an earlier study on adults by Konkle and Bess,(1974) they evaluated subjects performance using custom made versus stock earmolds (silioone elastomer silastic mold-custom; acrylic mold and stock insert). The seventeen subjects (twelve males and five females) with/mean age of 52 years, ranging 29-72, met the following criteria:

i) Had moderate - severe bilateral SN loss (40-80 dB IS0-64)

ii) A potential hearing aid candidate.

iii) Had no previous experience with amplification. The subjects were grouped according to audiometric configuration into:

a) Flat loss through speech frequencies with a mean PTA of 47 dB and average SRT of 42 dB.

b) Sloping configuration with PTA of 47 dB and SRT of 45 dB.

-TABLE 16 (A)

		Frequency (Hz)					
		250	500	1000	2000	4000	8000
Threshold	Group-I	30	40	45	49	51	51
dB HL	Group-II	25	30	50	60	70	75

Comparison between the two groups was done for a series of audiological tests including threshold for speech and narrow-band noise (NBN) using modified Hughson-Westlake procedure, most comfortable level (MCL) tolerance level and speech discrimination using Modified Rhyme Test.

The results obtained were as follows:

Table 16(B) HEARING AID EVALUATION DATA FOR ALL SUBJECTS.

Date. category	Listening conditions			
	Unaided	Insert	Acrylic	Custom made
NBN Th.dBHL.				
250Hz	26 ± 8	21 ± 6	22 ± 7	16 ± 5
500Hz	31 ± 9	24 ± 9	22 ± 7	18 ± 6
1000 Hz	39 ±10	29 ± 8	22 ± 7	23 ± 5
2000 Hz	45 ±10	34 ± 9	32 ± 8	27 ± 7
4000 Hz	53 ±10	39 ± 12	36 ± 13	32 ± 15

This indicates the paramount importance of utilization of custom made earmolds during evaluation of hearing aids, especially when there is difficulty in obtaining good acoustic seal in lieu of the better scores obtained on all tasks with the exception of MCL and tolerance measures.

Reason for improved performance with custom earmold:

The improved narrow band noise and speech thresholds with a custom-made coupler probably results because of A TIGHTER ACOUSTIC SEAL. An earmold, not permitting acoustic leakage transmits low frequency sound to the tympanic membrane without a reduction in strength. Conversely, an earmold providing a poor acoustic seal functions like a high pass filter. Therefore, the acoustic seal provided by custom made coupler permits less sound leakage and thus serves to enhance the level of sound pressure present in/the ear canal.

Regarding difference in discrimination between flat versus sloping loss configuration, the group with flat configuration exhibits considerably better intelligibility. Since many of the subjects with sloping configuration have near normal hearing in the low frequencies, the added amplification caused by the custom made coupler may serve to produce a masking effect onthe high frequencies. Greater improvement in discrimination is expected to occur if controlled venting of the earmold is employed.(Konkle and Bess, 1974).

Summarizing, it is clear that the relationship between the intensity of the low frequency portion of the speech signal (Fl range) and that of the higher frequency portions (F2 and above) is one of the very crucial factors in providing an intelligible speech signal to the impaired ear. In order to minimize the effects of upward spread of masking and temporal masking, low frequencies cannot be disproportionately amplified with respect to high frequencies. (Martin and Aickett, 1970; Danaher et al, 1973; Wilson et al, 1973; Danaher and Pickett, 1975? Konkle and Bess, 1974). The physical shape of the ear-mold and associated connections must not be overlooked in attempting to assess aided performance with a particular hearing aid, since the consequence of most changes in earmold conformation directly influences difference in intensity levels in first and second formant of the amplified spectrum.

Acoustic feedback control in hearing aid selection:

During hearing aid brial, acoustic feedback is a serious problem with high gain aids. The customary practice of using stock ear piece for trial prevents the use of hearing aid at high gain which in turn results in inadequate information regarding the suitability of the hearing aid as well as the benefit the case can derive from its use. This problem is overcome by making use of a custom earmold. When facilities for instant earmold making are not available, as is the case in India, the following helps to reduce the acoustic feedback.

i) Use insert earpiece attached to receiver instead of stock earmold to reduce the feedback. Insert earpiece has to be soft tipped one so as to not cause pain and irritation of the ear canal.

ii) Aural domes can be fitted in addition to the stock earpiece attached to the receiver, but the reduction in acoustic feedback is comparatively less.

iii) Sealing the leakage of sound around the receiver with plaster of parts, soft variety of bees wax and zalgen; of which bee's wax when used in combination with custom or stock earpiece is the most effective (Babu, 1973).

Summary:

The present section emphasizes the following points pertinent to earmolds to make the hearing aid fitting a success

1. REDUCE ACOUSTIC FEEDBACK connected with the use of earmold during the selection of hearing aid.
2. USE CUSTOM MADE EARMOLD for testing purposes.
3. EMPLOY APPROPRIATE ACOUSTIC MODIFICATION to alter the hearing aid response characteristics, these being the key note to successful fitting.

CHAPTER-10

TEACHING EARMOLD FITTING

'An ounce of practice is worth tons of theory' - a popular adage of relevance to teaching earmold fitting to the hearing aid user.

Prior to teaching earmold fitting, three non-skill aspects ought to be considered as proposed by the British Society of Audiology (1984).

i) Physical capability i.e. digital dexterity and sensitivity to manipulate the earmold "A good rule of thumb is to consider patients who are able to brush their hair as capable of being taught to fit their own earmolds".

ii) A good fit is of prime importance. For a dextrous patient, fitting an ill-fitting earmold becomes an unfeasible Herculean task. The only solution that remain* is to procure a new earmold.

iii) An earmold may be a good fit, yet its shape may prevent easy insertion. If acoustics permit, the earmold meatus can be shortened to 5-10 mm to make insertion easier. Also skeleton mold is relatively easier to handle than the conventional or shell mold. In some cases it is possible to trim the mold right down to a canal lock version, the essence is that these alterations should not affect the acoustic seal.

Basic training techniques;

As highlighted earlier ascertain the appropriateness of theaarmold fitting onto the patient's ear peior to guiding the potential user. This aids in

i) Checking the earmold fit;

ii) Determining the easiest route for final insertion? and

iii) Noting any areas of difficulty, eg. an acute bend in the meatal entrance.

There is no single 'correct way' of teaching earmold fitting, each client requiring a custom-designed instruction format based on his abilities, attitudes and pinna - earcanal contours. However, mastery of a sequence of key features of earmold fitting is imperative, including -

i) Identification of the landmarks of earmold and ear.

ii) Appropriate orientation of the earmold with respect to the ear; and

iii)Fitting the earmold onto the ear.

Basic explanation demonstration and trial practice suffice for most clients. Failure in learning to fit the earmold implies the necessity to concentrate on the key features and errors causing problem, eg.

i) Anticipation errors occuring when patient skips a stagey for instance failure in proper orientation of the earmold and thus badly placed to continue the sequence.

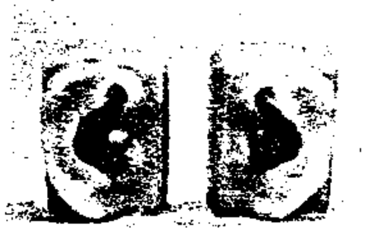
ii) Perseverance errors being incidental to the patient's persistence in making the same mistakes because of the inability to unlearn the incorrect procedures.

These two errors heighten anxiety, further impeding the proper fitting of the mold. Repeated abortive attempts to fit the earmold calls for fresh approach for which various suggestions have been given.

i) Delk (1974) recommends the use of a mirror without comitting the mistake of having the client practice too often in front of the mirror? the reason being the inconvenience of having a mirror when an earmold needsto be inserted. Hence transference to a mirrorless condition is of vital importance.

Along wide this training, spouse or a close friend should be shown what the earmold should look like when in place. Also, there are occasions when the client is unaware of the acoustic feedback audible objectively and this is the time "when a feller needs a friend" and someone to help him eorrect the problem.

ii) Dissenting the use of mirror that "mirrors should be used only as a last resort, since they cause more confusion than benefit for many patients, Loavenbruck and Madell (1981) recommend the use of rubber dummy ears and practice inserting the mold into the rubber ear first.



Fig, 59 : Rubber ears.

Despite this practice, if inserting the earmold remains problematic, following alterations prove helpful -

a) Ordering the nab removed for the geriatrics and those who have dexterity problems.

b) Also with older patients, if the loss permits, shorter or cutdown molds should be used owing to their easier insertion.

c) Canal molds or canal lock molds may prove useful for patients who continue to have trouble inserting the mold (Loavenbruck and Madell, 1981).

iii) **Increasing gap technique** (proposed by Hearing Aid Audiology Group, British Society of Audiology, 1984)

Failure to learn fitting with the basic technique requires the use of this patient-paced technique aiming to teach successive stages, each having an "increasing gap" from the final, fitted position "start with the earmold correctly inserted. Ask the patient to remove the mold in successive stages and after each stage to replace it. Proceed to the next stage only if the patient can manage both halves (removal and replacement) of the present stage".

This technique follows the rationale that beginning with the earmold in the ear and working backwards enables the client to learn the final, more difficult actions first. This requiring repetition, provides for more practice in fitting.

The technique comprising of four stages include -

Stage -l:The patient is shown how to lever out the back curve in the earmold using the thumb nail and how to push it back in. At this stage, the earmold does not leave the ear and so the patient can concentrate on the final fitting action, pushing the back curve of the earmold into the ear. Once the patient accomplishes this successfully,he/she is geared on to the next stage.

Stage-2: The patient is asked to remove the earmold completely but hold it close to the ear. Using the procedure learnt in stage-1, the patient levers out the earmold. He is then shown how to grasp the back curve between finger and thumb before removing the earmold from the ear. This time the earmold/ear contact is lost, bat their close proximity ensures good orientation. The patient is then instructed to reinsert the earmold and, if necessary, guided in the initial fitting action (in this case, inserting top and bottom prongs). The final setting action should present no difficulties, as it has already been learnt in stage 1. Once this is successfully repeated, the patient is moved on to stage 3, wherein the gap between earmold and ear is increased further.

Stage-3: The patient is asked to remove the earmold from the ear and look at it, now both contact and orientation are lost, but the patient still has the earmold grasped correctly for eventual fitting into the ear. Instruction for correct fitting, with some help with orientation is provided. With this, one should manage a successful fitting, following this, the patient moves en to the final stage in the sequence.

Stage-4: The patient is asked to remove the earmold completely and place it on the table, thereby losing contact, orientation and grasp. The client is instructed to fit the earmold and may require some help with getting the correct grasp on the mold (back curve between finger and thumb). Once this is managed, the remaining actions are familiar. The earmold is brought upto the ear and oriented correctly the top and bottom prongs are inserted and the back curve is pushed in. Once the patient repeats the sequence successfully, he is in a position to manage earmold insertion on his own.

The succeeding task is to teach the client to fit the hearing aid and manipulate its control.

In essence, the increasing gap technique involves breaking down of the earmold fitting skill into stages taught sequentially. For the client to be geared to the next stage, successful repetition of that stage is a must,each stage being embedded in the sequence. The stages may differ for patients, but the sequential action is the core of this technique aiding in redaction of both anticipation and perseverence errors. This implies that the earmold can make or marr an otherwise satisfactory fitting if the technique of fitting is not highlighted to the client, failing to learn from the basic technique, and hence the importance of the same in acceptance of amplifications.

CONCLUSION

To individualize the earmold fitting and understanding competency level of the client, helping in his quest for more efficient sound dictates the responsibility of the hearing health professional. Many a scientist who claim to have"the solution to the best fit of the ear" have so often yelped a loud Eureka: .... but one I/solution brings out another problem. Here, earmolds then .. and the current solved status of some of the problems faced have been discussed withthe emphasis that the coupling device ought to be custom made; viewed as an integral part of the total hearing aid system, capable of making or marring satisfactory fitting of an otherwise carefully enginered transmission route. Also discussed is the role of earmolds in hearing aid selection procedure and the need to ensure that the transmission route is not radically altered through the mold keeping in view the effects that arise from the matching characteristics of the middle ear mechanism and natural resonances of the external ear being preserved.

Lets recollect that "Our approach must be a scientific approach and not that kind of conceited scientific approach which thinks that what you are doing now is the last word on that subject" - Nehru.

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