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Distance training course

The hearing aid rehabilitative therapy in deafness

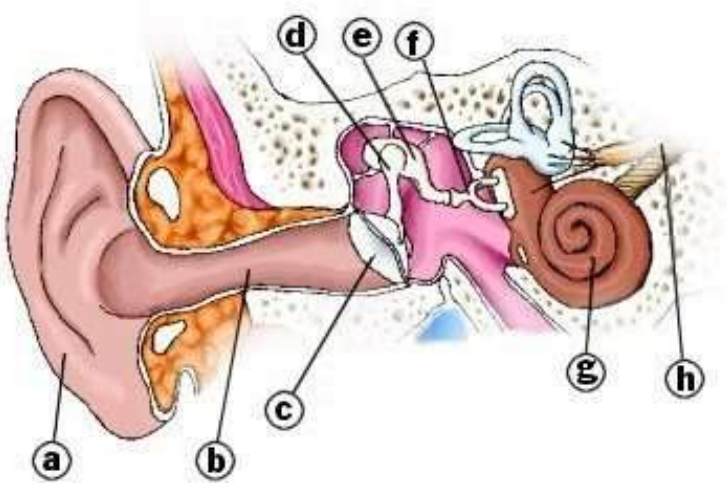
Cap.1 Notes of Anatomy, Physiology and Auditory system Pathology

by Enrico Fagnani

Let's see how ear is made and how work

External ear, made by auricle and auditory duct, receives and canalises environmental sounds towards the tympanic membrane. Sounds, that we define sound-waves, arrive to the tympanum, membrane like the leader of a drum, and make it vibrate.
These sound-vibrations are transmitted before all to the ossicles chain (called malleus/hammer, incus/anvil, stirrup-bone/stapes) placed in the cavity of medium ear, than to internal ear. In the external ear there is a very important organ snail-shaped: the cochlea. Here the sound-vibrations are transformed in electric impulse that are dispatched to brain through auditory nerve. Only when the electric signal arrives to the brain we listen and we are able to appreciate sound features: grave or high frequency, faint or loud intensity, agreeable or disagreeable timbre.

The auditory apparatus could be divided in three sections: external ear, medium ear, internal ear.

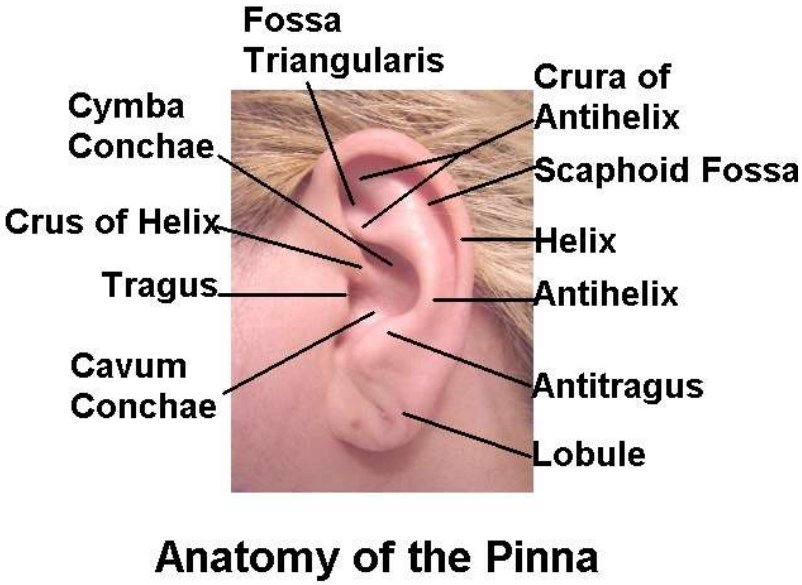


The image of ear.
a) external ear auricle
b) external ear duct
c) tympanum
d) *e) f) medium ear ossicles chain*
g) internal ear cochlea or snail
h) auditory nerve

External ear

It's made by auricle and auditory duct.

It's fundamentally well known the auricle morphology because it has a very important role in auditory hearing aid. The auricle, in fact is used as support of auricular file (cochlea) for retro-auricular hearing aid BTE or it even gives hospitality to the same hearing aid in case of Endo-auricular apparatus/ware.



Anatomy of the Pinna

External ear: terminology

The auricle is made by cartilage covered by skin. Skin layer is really fine and delicate, for this reason if the cochlea or the auditory ware shell don't perfectly reproduce the auricular morphology it could be generated troublesome and grievous sores.
The auricle catties on the following functions:
- it picks up, conveys and reflects sonorous waves.
- it favours the space localisation of sonorous wave.
The auricle, only to determine sonorous frequencies, acts as amplifier. The structures that made it, are usually divided in front-one (concha-tragus), that pick up shrill frequencies (superior to 1000 Hz) and back-one that give a fundamental contribution for grave/low frequencies (up to 1000 Hz).

The auditory duct is a tube with an extremity closed by the tympanum and the other one that's open in auricle. The physics dimensions of the duct are such as to made a sound amplification with frequency included between 2000Hz and 4000Hz. This allows to ameliorate consonants and not background noise prevalent in low-frequencies.
The duct is a tube with two curves that are particularly marked in babies; these curves are used to "hook" the cochlea or the endo-auricular to the ear.

NB A very important moment of auditory hearing aid application is the print making, it means the execution of duct and auricle "mould". Thanks to this print it's realised cochlea or endo-auricular apparatus made to measure. An error ,minimum too, in the print making can bring to pain in the using of hearing aid and even to failure of hearing aid application. To effect the print it necessary to use a soft paste that, inserted in the duct with a syringe, hardens in few minutes.

Medium ear

Medium ear is made by tympanum membrane, ossicles chain (made by three small ossicles called stirrup-bone/stapes, incus/anvil , malleus/hammer), Eustachian tubes and mastoid cells. Furthermore there are two small muscles: tympanum Tensor and Stapedius that warrant the ossicles system mobility.

<u>Function of medium ear</u>

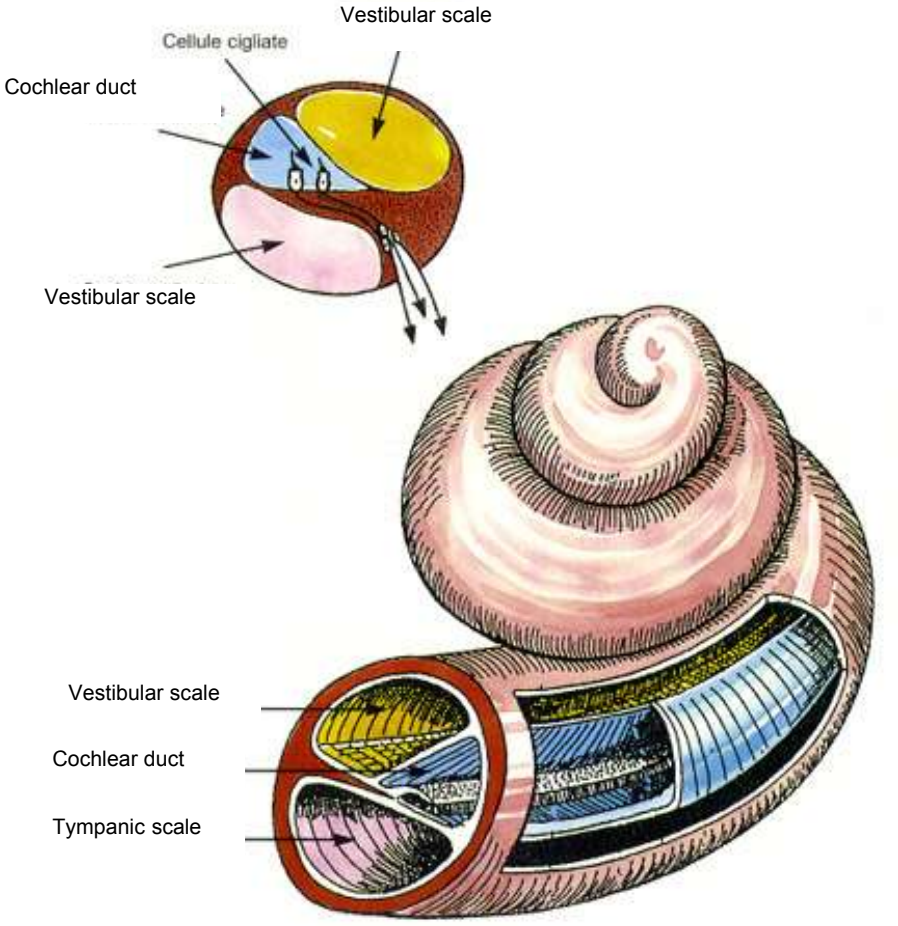
The medium ear acts as intermediary between the external and internal ear.
The sonorous vibrations converged by outer ear and by duct are picked up by the fine skin membrane of the tympanum. The tympanum-ossicles system transmits and amplifies the sonorous vibrations that are transfer from air (tympanum) to liquid state (perilymph) presents in the internal ear (cochlea). This allows a loss of 30dB more or less, that however it's recovered with an amplification of 30-40dB thanks to two recovery systems of typical medium ear: surface-ratio between tympanum surface and vestibulum surface like 1/7 (nail effect) and ossicles levers system that produce a gain in width of sonorous vibrations transmitted. So this system allows the sound transmission from external auditory duct to cochlea: therefore it acts like transformer, it couples aerial and liquid state with different impedance, limiting the problem of dispersion.
The tympanum acts as pressure receiver only for 2/3 of its area and the maximum vibrator contribution is made by the area under the umbus, conveyance zone of sonorous waves from external ear. Tympanum membrane has deadening properties, that allows to the stimulus cessation reducing 26% the vibrations width. Endo-tympanic muscles, tympanum tensor and stapedius make rigid the ossicles chain increasing the impedance of ossicle tympanum system, protecting labyrinthine liquids from violent impulses, increasing the inter-ossicles

cohesion to avoid infractions or distortions of high intensity sounds, influencing the vibration frequency with the preference of some frequencies.

Internal ear

Internal ear is seat of peripheral nervous receptors of auditory apparatus (cochlea) and vestibular apparatus (labyrinth) that presides at balance control. In this seat we will be attended to the cochlea functioning. The cochlea is a thin tube retorted in spiral that contains thousands nervous cells immerse in watery fluid called endolympha. These nervous cells called ciliated cells have cilia that, as thin hair, are moved by endolympha vibrations.
Sonorous vibrations that coming from ossicles chain are transmitted by the last ossicle, the stirrup-bone/stapes, through vestibulum to endolympha of cochlea. The ciliated cells have the capability to transform the cilia vibrations in nervous impulses that are picked up by auditory nerve and that are forwarded to superior nervous centres.

Internal ear: cochlea



Notes of the principal pathology of auditory system: the hearing loss (deafness)

Each time that a damaging event hits organ of hearing we have a decrease of auditory capability. This compromising will be more or less important according to the seat and the

importance of the damage. A reduction of auditory information is the result and it allows an alteration or impedance of verbal communication.

Kinds of hearing loss

Deafness of transmission

This kind of deafness is due to lesions of external or medium ear caused by otitis or a malformation of auricle, external auditory duct or ossicles, etc. The lesion doesn't usually affect the "noble" part of ear, it means that cochlea and hearing ways through which sonorous impulses arrive to cerebral cortex. The damage, from auditory point of view, is never serious: the person listens and distinguishes words sounds as long as they are pronounced with an intensity superior to normal values.
On audiogram the auditory loss could be quantify as follow:

Tonal audiogram

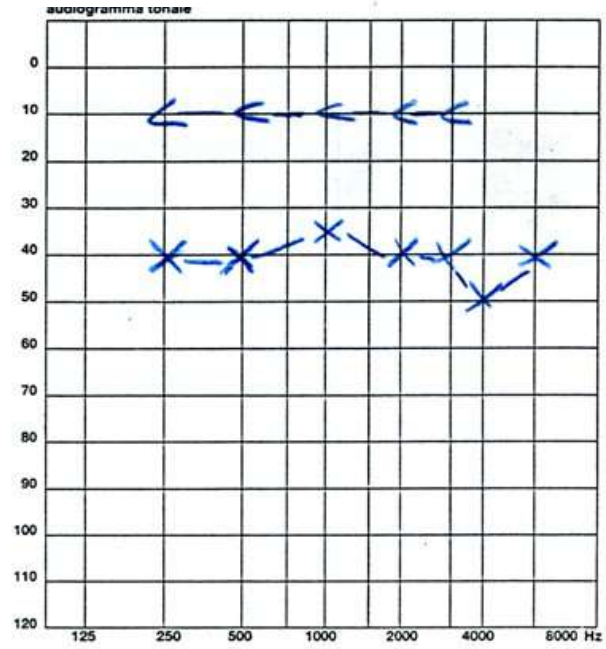


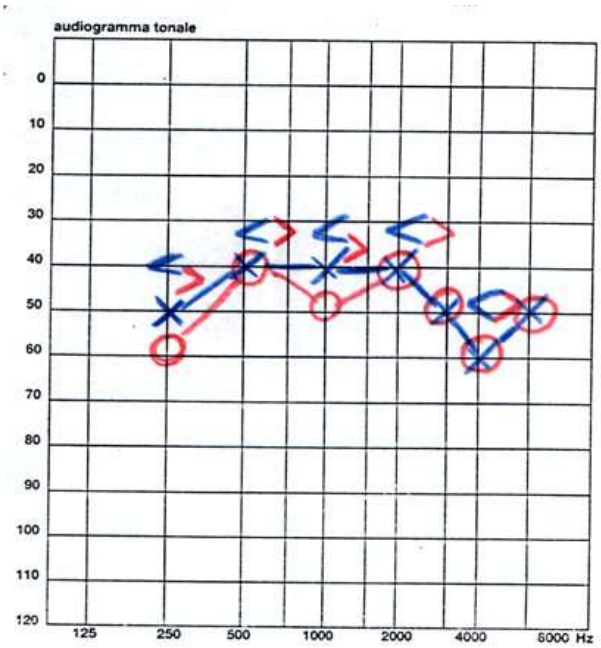
foto audio1.jpg

as it's possible to see there is a difference between threshold by air and by osseous; the latter attests the well functioning of internal ear.

Neurosensorial deafness

The lesion interests in more or less important way the internal ear (cochlear deafness) or auditory nerve (retro-cochlear deafness). We report a typical audiogram of this deafness form which it's possible to note as the threshold by air way coincides with which by osseous way.

Tonal audiogram



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Deafness of mixed type

There is when there are in the same time the two forms over describe. Babies, in winter season, are liable to catarrhal otitis that could make worse a neurosensorial auditory deficit eventually presents. However the worsening is temporary because it's solvable with an opportune therapy.

Degree of deafness

On the basis of the classification established by Bureau International d'Audiophonologie, according to the auditory loss expresses in decibel (dB), the deafness could be:

light The threshold is between 20/40 dB: only the whisper voice is not perceived.

medium The threshold is between 40/70 dB: the voice emitted in a normal conversation is not perfectly heard: to a superior intensity the person is able to perceive sounds but he has some difficulties to discriminate words. Particularly if the auditory deficit is present in a baby from him birth or in the first period of his life, the language learning, without auditory hearing aid, occurs in limited way and always late in time.

grave Threshold between 70/90 dB: the person who has this deficit perceives only some sounds of words even if they are pronounced to an faint intensity.

heavy Threshold the same or superior to 90 dB: it exists three levels of heavy deafness; to the third one are perceived only sounds graver and more intense having a notable vibrator component, as roar engine, slam door and few others. If the word is not heard it means that without a hearing aid aid associated to labial reading it's impossible any learning form of verbal language.

NB When can deafness arrive?

In any moments:
before birth (hereditary, viral, toxic,.. origin)
at birth (asphyxia, icterus, etc.)
in first months of life (meningitis, etc.)
in course of years (cranial trauma, intoxication, viral forms, presbiacusia, etc.)
The baby deaf from birth (*pre-verbal deafness*) is not able to develop language in normal way without an adequate hearing aid/rehabilitative therapy. The baby becomes deaf when he was 3/4 (*peri-verbal deafness*) looses almost completely the language if he's not parenthesised in time.
The person becomes deaf after the completely word acquisition (*post-verbal deafness*) maintains almost unchanged his linguistic patrimony; what is compromise, if are not take right measure, is verbal communication with inevitable consequences on social and psychological level.

Cap. 2 THE AUDITORY HEARING AID

by Luca Del Bo

Basis concepts, terminology

The term auditory aid includes all devices that the technology places disposal at all people who has hearing problems, it means:

- auditory hearing aid;
- installing hearing aid;
- **cochlear** implant;
- not prosthetic aid.

Auditory hearing aid

With the term auditory hearing aid it's common to indicate the usual external auditory instrument to set behind ear or in the auditory duct. Synthesising the auditory hearing aid amplifies in adequate measure to "compensate" the loss of sensibility due to deafness.

Auditory hearing aid models

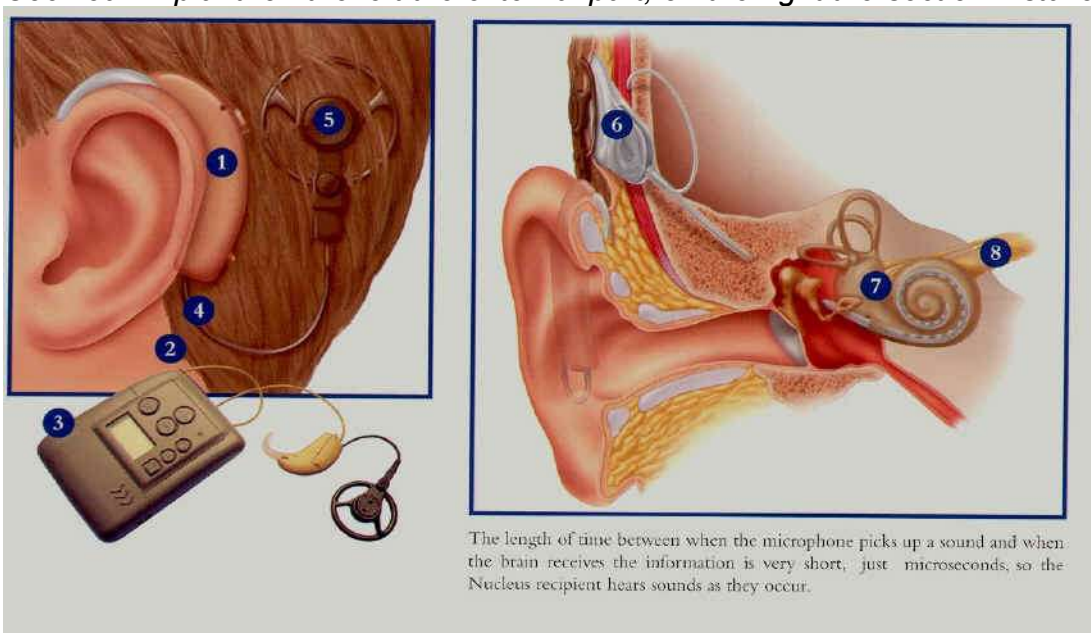
Installing hearing aid

The installing hearing aid are a middle course between auditory hearing aid and cochlear implant. In fact they are a sort of auditory hearing aid puts under the skin through a chirurgical operation. The installing hearing aid could be used in light and medium deafness but their use today is in experimental phase. It exists, always in experimental stadium, semi-installing hearing aid too. To deepening cross reference to paragraphs in end chapters.

Cochlear implant

Cochlear implants are used only in heavy deafness when the deafness doesn't allow the satisfactory use of auditory instruments. The cochlear implant is applied under the skin in permanent way with a chirurgical operation ant it rouses with electric impulses the auditory nerve. The cochlear implant is made by an external part similar to a retro-auricular auditory hearing aid.

Cochlear implant: on the left the external part, on the right the section installed.



Not prosthetic aid

Besides auricular hearing aid there are some devices, called not prosthetic aid, that helps the person with hearing problems to unwind a normal life.
Among them we find: the telephone, cordless too, with amplify bell, flashing indicator and adjustable volume, earphone for mobile phone too equipped with a magnetic field, alarm-

clock with vibrator to put under the pillow, the stroboscopic lamp signaller for doorbell, the watch with vibration and many others easy and really useful devices.
Among really useful aid there are FM systems used by students to hear lessons. The FM system is made by a microphone integrated with a little FM radio-transmitter that, placed near the speaker, monitors the voice and transmits it to a small receiver placed on auditory hearing aid (usable only with retro-auriculars). So, if the user can hear the lesson without interferences of background noise. The use of FM is recommended for all students, from nursery-school to university, with deafness from medium-grave to heavy one. The FM system can be used to listen to music too. A simplify version of FM, usable to whom doesn't have auditory devices, are amplify earphones without leads. These are suitable for all people who has a modest auditory loss of the listen of tv.

Models of auditory hearing aid

Hearing aid by box

Hearing aid by box: the device has form of little box and lodges microphone, battery and amplifier, it's usually place on chest, under clothes or in pocket. From the box stars to thin electric leads that bring electric signal amplify to two miniaturized loudspeaker (receivers) placed on person's ear. Today the hearing aid by box is overcame for performances and aesthetic by the retro-auricular hearing aid; but it's still used in developing countries because of its low costs, exercise and servicing.

Hearing aid by glass

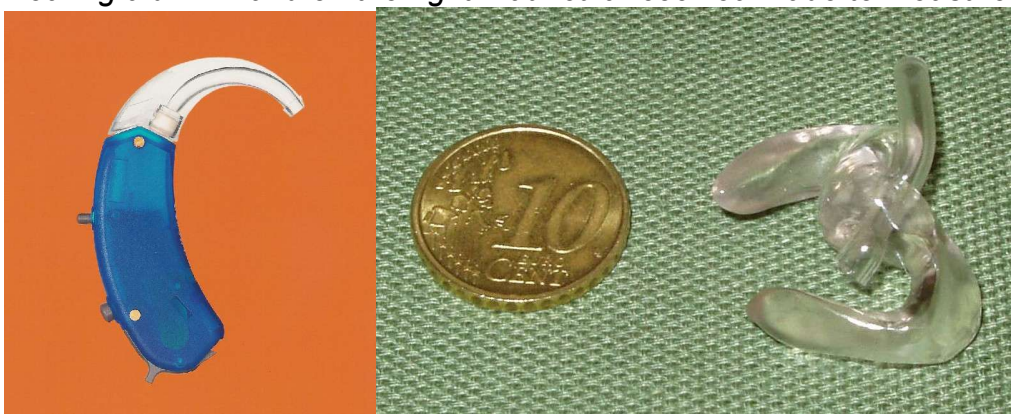
Hearing aid by glass: all the components of the hearing aid are in one or in both the bars. There are two kinds of hearing aid by glass: the hearing aid by air glass, today missed and substituted by retro-auricular hearing aid or endo-auricular one and the hearing aid by osseous glass. The device by osseous conduction is suitable for light and medium deafness, in which the auditory lowering is due to transmissive deafness with permanent perforation of the tympanum. Today the use of these kind of hearing aid is really limited because they are often substituted, with major satisfaction by the user, by retro-auricular or semi-installed hearing aid

Hearing aid by osseous glass

Retro-auricular hearing aid

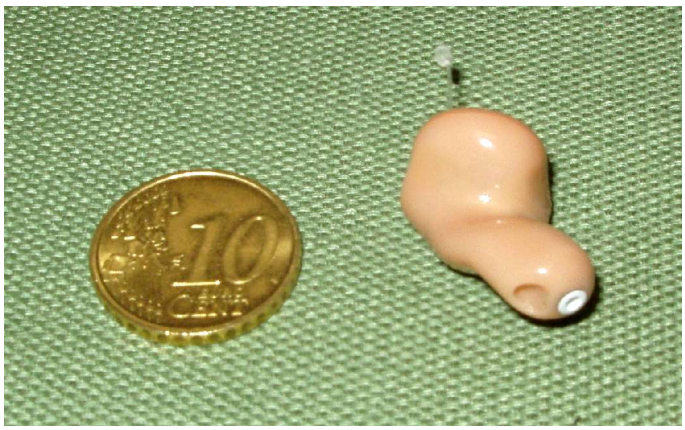
Retro-auricular hearing aid: (acronym BTE from English Behind The End) is placed behind the ear on the auricle to which it leans on and fits thanks to its anatomic mould. The retro-auricular hearing aid is always combined with auricular file (commonly called cochlea) that, placed in the auricular end in the duct, has the duty to converge sounds towards tympanum. A little plastic tube links hearing aid to cochlea. The cochlea is made to measure with silicone material in rigid or soft plastic. The retro-auricular hearing aid holds all circuits, microphone, loud-speaker and battery. The remarkable versatility of retro-auricular hearing aid allows their use in the totality of deafness.

Hearing aid BTE and on the right auricular cochlea made to measure



Endo-auricular hearing aid

In this kind of hearing aid all elements of retro-auricular hearing aid are further on miniaturized and they find space in cochlea. This allows a comprehensible aesthetic advantage above all in the endo-auricular CIC that are directly placed in the duct. These, as all other auditory hearing aid, are usually applied in the waking up and removed before retiring from the same user. The endo-auricular hearing aid could be applied in the 70% of deafness with the exception of grave and heavy deafness and of babies deafness up to 6-8 years.



To sum up this prospect on auditory hearing aid it's important remember that today are used endo-auricular hearing aid and retro-auricular one with a slow but constant increasing of endo-auricular spreading.

NB endo-auricular or retro-auricular hearing aid?

Today the endo-auriculars could be used in all kinds of deafness with the exception of grave and heavy deafness and in babies up to 6-8 years. It's necessary not forget that the endo-auriculars are in made less robust (they are always devices realized in unique piece unlike the retro-one realized in series of considerable number) and however more subject to periodical servicing.

For this reason it's necessary to attend to the following rules:

- address endo-auricular hearing aid made by leader seat of sector that uses rigid methodologies of quality and reliability and that has faced and solved on a considerable number of pieces the drawback of handcraft productions,
- prefer hearing aid with para-cerumen type wax buster however that could be clean by the same patient,
- the servicing is more frequent and more demanding than a retro-auricular device, for this reason the application of these hearing aid is not advisable in babies younger than 6-8 years,
- the adaptation process could be longer and could need patient's active collaboration, also for this reason the application of this kind of hearing aid is not advisable in babies younger than 6-8 years

Auditory hearing aid or cochlear implant?

It's impossible give an univocal answer to this question. The choice among these aids has to be made with the advice of specialist in implantology, logopaedist and audio-hearing aidt. However it exists some intransgressible points:

- in baby the implant has to be preferably carry out precociously starting to 2 years of life, before it's necessary the use of auditory hearing aid and of rehabilitative therapy, in an adult with important and congenital deafness who has never exploit the hearing, doesn't wear auditory device, the implant is unadvisable,
- the implant is usually used in total or heavy deafness that doesn't find any benefits from auditory devices,
- the implant has to be effects in a centre of referring that guarantee the presence of a close team composed by a oto-surgeon, clinical specialist, logopaedist, audiomertist, audiohearing aidt, neuropsychiartrist.

Installing hearing aid for neuro-sensorial deafness

The installing hearing aid is an auditory device permanently install under the skin without visible part to the external and it's destined to correct neuro-sensorial deafness due to a lesion of ear nervous receptor (the cochlea) or of auditory nerve.

Even if today it's possible to use experimental hearing aid models completely installing, their diffusion on large scale will be possible only in some years when the technology will be tested and it will be available rechargeable batteries reliable for all the during of the hearing aid (10-15 years). A "short cut" to instal hearing aid will be in part installing hearing aid. Since the half of 90 years in USA and then in Europe it has been developed a hearing aid partially installing Vibrant Soundbridge. The Soundbridge is made by an external part little bigger than a coin in which is placed the microphone, the feeding battery and digital circuits of sound elabotation, that, through electromagnetic low-frequency and reduced intensity impulses, dispatches elaborated sonorous message to internal part installed under the skin. The heart of the Vibrant is a magnet with mobile mass big as a rice-grain that, firmly fixed to the ossicle of the incus/anvil of medium ear with a chirurgical operation, it transmits amplified sonorous

vibrations to ossicular chain. The patients who has received the Sounbrgidge hearing aid report a good use satisfaction: good sonorous quality, comprehension increasing in noisy environments, disappearance of occlusion effects and of troublesome whistle, annulment of drawbacks due to earwax, allergy, not suitable cochlea. This hearing aid is reserved only to particularly users because of its high cost, because of the necessity of a chirurgical operation and of a limited amplification.

Semi-installing hearing aid for transmissive deafness

The hearing aid for transmissive deafness are used since more a decade to correct a problem of medium or external ear functioning. For example they are used in case of chronic ear infections that don't allow the traditional hearing aid use or in external ear malformations.
This kind of hearing aid is completely external and it works with the osseous vibration principle. In fact a osseous vibrator in the device transmits the auditory vibrations directly to the mastoid bone (behind the ear) using a screw in titanium permanently installed in the bone. It's a kind of screw like that used in dental plants that are applied with a simple operation in local anaesthesia.
Unlike the technology used for installing hearing aid, this is by now tested with success on tens of thousands patients in all worlds. The only osseous vibration hearing aid available is the BAHA made in Europe and also in Italy installed by numerous centres.
Its installation needs a little operation to insert a metallic screw on a level of the bone, behind the ear. The screw will successively become integrated with the bone assuring the stability of the plants.
To the external slope of the screw is successively linked to the external part of the device, removing or insertable according to necessity, it's represented by a little vibrator big as a stamp, virtually invisible if it's hidden by hairs. In this way the signals intercepted by the external device are transmitted by osseous way directly to labyrinthine liquid of internal ear.
The operation for the installing of the screw is possible in adult with local anaesthesia instead of in baby it's usually necessary total anaesthesia. The application of BAHA doesn't compromise in any way the future possibility of micro-chirurgical otological operations or the application of other auditory hearing aid models. The patient has to pay attention on hygiene of the skin looking out upon the installed screw that will be periodically controlled by qualify staff.
This methodology could be used in the rehabilitation of mono-lateral deafness too, thanks to the contemporaneous stimulation by osseous way of contro-lateral wholesome ear.

semi-installing prsthesis BAHA

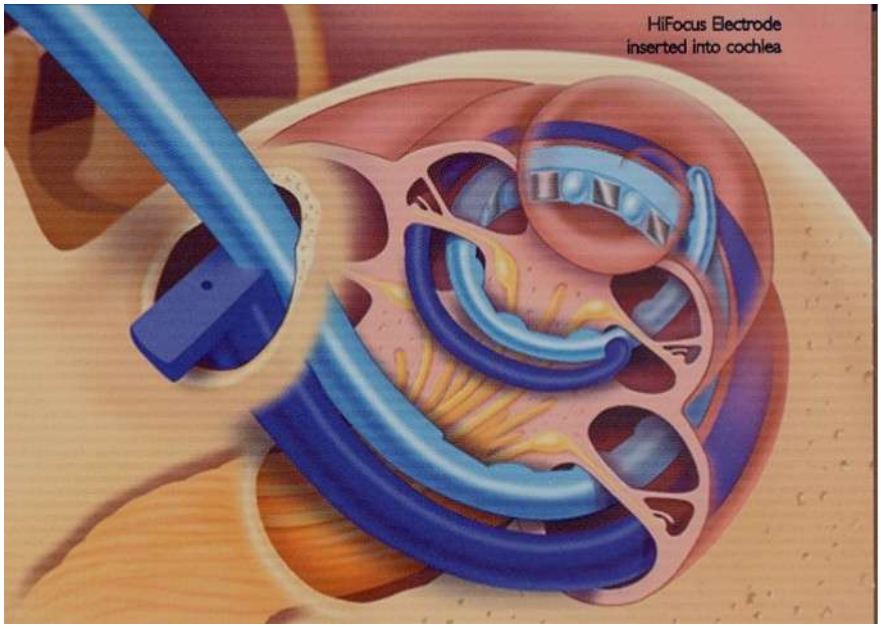
CROS or semi-installing hearing aid by osseous way for mono-lateral deafness

For patients who already has an important loss of auditory capability only by one side caused by a pathology or a previous chirurgical operation, today exist the possibility to recuperate the functionality of binaurale hearing.
Although in normal condition for auditory comprehension is enough only one side on, patients in this situation have a lot of voice comprehension problems when the only hearing ear is engaged in a phone conversation, in car, in meetings, in noisy environments and in the localization of sound provenience.
For some time a system to help mono-lateral deafness is available through a couple of hearing aid retro-auricular by air way. This system called CROS (Controlateral Routing Of Signals) needs a microphone in the covering of a reto-auricular hearing aid placed in ipoauditory side and a auditory hearing aid in wholesome side.
Two devices are linked through a thin threat placing behind the nape or under the hairs or by a transmission system without threats that transports auditory information from deaf ear to the other side make “working” the wholesome or less deaf ear for the unusable other too.
This methodology, even if effective and pleasant by the patients as hearing satisfaction, is always still less used by audiohearing aidt.
A new methodology exploits the capability of osseous transmission through the cranium to restore the auditory perception of stimuli coming from ipoauditory side directly stimulating internal ear of wholesome side. This is realizable through hearing aid application installing by osseous way (BAHA), the same by which the use is already tested for more than twenty years in same transmissive hearing loss forms. The small hearing aid hidden in hairs, behind deaf ear, is able to stimulate by transcranial way, through auditory vibrations naturally transmitted by cranial bone, cochlea of wholesome ear.

Cochlear implants

The big revolution of technology and of knowledge on functioning of internal ear allows through cochlear implants to restore a well auditory functionality also in heavy bilateral ipoacusie that couldn’t use an auditory hearing aid. Unfortunately medias usually identify cochlear implants with picturesque terms like “bionic ear” or “artificial ear” that only contributes to generate confusion and false hope in people who suffers of deafness and in theirs families too.
Cochlear implant isn’t a device like an auditory hearing aid because its role isn’t to amplify the entrance signal, but that to transform the sonorous wave in an electric stimulus, “jumping” the whole damaged system of cochlear cells and direct electrically stimulating the fibres of auditory nerve. The duty of the implant is that to substitute the function of cochlear cells, this makes it available in cases of heavy limitation of internal ear (cochlea) functioning as in heavy deafness.
The implant is ,at all effects, a semi installing device and it’s made by two different parts, the internal one placing with chirurgical operation under the skin and the external one placing behind the ear like the retro-auricular hearing aid. the internal part is constituted by a receiver placed, through chirurgical operation, in suitable billeting to the level of mastoid bone behind the ear, from which originates a little cable that is placed directly in the cochlea through medium ear and the opening of the cochlea. The cable finishes in a series of electrodes (to 8 from 22 electrodes) that represent the terminal effectors of the same implant, able to stimulate nervous fibres. The external part of the implant transmits through the skin the signal elaborated by the digital processor placed in extern.
The possibility of this kind of implants, in auditory terms, progresses more and more, but it’s fundamental remember that this solution is applying only in serious bilateral deafness and not in common forms of neurosensorial ipoacusie. Patients, who has an implant could, in same cases, speak to the phone through the most sophisticated devices and recuperate an excellent auditory capability, however it’s necessary not forget that, for the success of the operation, it’s essential a careful selection of candidates, the precocious application of the implant, a right

regulation of the same implant and a fit re-educative period. Today the cases indicated for the implant are the heavy bilateral deafness of cochlear kinds with integrity of auditory nerve fibres.
It's important to pay attention on infant deafness of heavy level for which the indication to the implant is a scarce take with auditory hearing aid. In this case the age of ideal application is 2 years old to allow a correct auditory stimulation in language learning stage. Retro-cochlear deafness due to an insufficient or null functionality of auditory nerve, fortunately really exceptional and generally due to benign tumour of brain (neurofibromatosis or neurinoma), could instead avail of implant to encephalic trunck that are different from cochlear implant only because of the electrodes shape and placing of electrodes to the level of auditory centres of encephalic trunck overcoming the function of the same nerve. It's important remember the extreme criticality of the operation of implant positioning to the trunck that needs deepened experience of neurosurgery.
It's probable that in not far future the technology of installing hearing aid and of cochlear implant will replace that of auditory hearing aid realizing a real bionic ear able to replace the cochlear function for all level of deafness.



Electrode of cochlear implant correctly placed in the cochlea.

Technologies of auditory hearing aid

Traditional auditory hearing aid

Till few years ago the hearing aid were disposable only in traditional version and they could be fitted to patient's exigencies only through the volume roller and two or three little screw that alter the auditory yield. Besides a traditional hearing aid is analogical and it doesn't allow amplifier curves not linear, two or more independent channels of sonorous elaboration, digital circuits, programmability and suppleness to patient's exigencies.
Therefore the use of these devices, less flexible to hearing patient's exigencies, remains narrow to few cases where the control of costs is the primary exigency.
Now the traditional hearing aid is used in application of total charge of public health in developing countries for economic reasons. However even with a traditional hearing aid well

adapted is possible to arrive at hearing results inferior to which reachable with modern digital but satisfactoriness.

Auditory hearing aid digitally programmable.

Digital technologies applied to traditional hearing aid has given life, in 90's years , digitally programmable devices with circuits of traditional sound elaboration (microphone, amplifier, receiver) adjustable through an external computer. In this way the audiohearing aid technician is able to adapt the sonorous elaboration to user's exigency by computer through more or less ten controls. The digitally programmable are devices that use advanced electronic circuits as not linear amplifiers, WDRC compression to wide dynamics, low distortion receivers in D class, ultra-directive microphones, ultra-power amplifiers. The programmable hearing aid are available in retro-auricular and endo-auricular version up to little pre-tympanic "to disappearance" in the duct.

Today the digitally programmable hearing aid have gained their important space for the heavy deafness hearing aid because they arrive to powers not equally reachable by digital ones.

Digitally programmable hearing aid have the following features:
- are well adaptable to patient's exigencies of hearing;
- in case of variation if deafness level can be programmed again for new hearing exigencies:
- available in extra power version for heavy deafness;
- application range: all deafness of light, middle, important and heavy deafness;
- hearing aid models available: retro-auricular, endo-auricular and peri-tympanic.

Auditory digital hearing aid

The approach philosophy to patient is changed with the arrival of digital: before the user was obliged to adapt himself to the auditory aid; in fact, today too, traditional hearing aid allow a limited edge of regulation, often not adequate to ipoacustic subject's exigencies; with digital hearing aid, or better with auditory computer, as they have to be called, the hearing aid is able to adapt itself to user's exigencies. With the most advanced auditory digital hearing aid is really possible to elaborate in automatic and contemporary way the sounds and to transmit them to user's ear.

The digital hearing aid is defined auditory hearing aid because it's a really miniaturized computer till the measure of a retro-auricular or even an endo-auricular; sounds intercepted by the microphone are transformed in digital impulses, digitally elaborated by a microprocessor and transformed again in sound and transmitted to tympanum, the digital technology needs big investments and not always the word "digital hearing aid" can function as magic wand. In fact are available digital hearing aid for really different features and potentialities; only the most modern digital hearing aid have the elaboration power enough to allow doing the "quality jump" as to analogical programmable ones. We speak about "artificial intelligence" so about devices that are able to autonomously elaborate with intelligence sounds ameliorating comfort and hearing performances. The application of digital needs an important technical and audiological training of the staff without which there is the risk of vanishing the potentiality offered by technology.

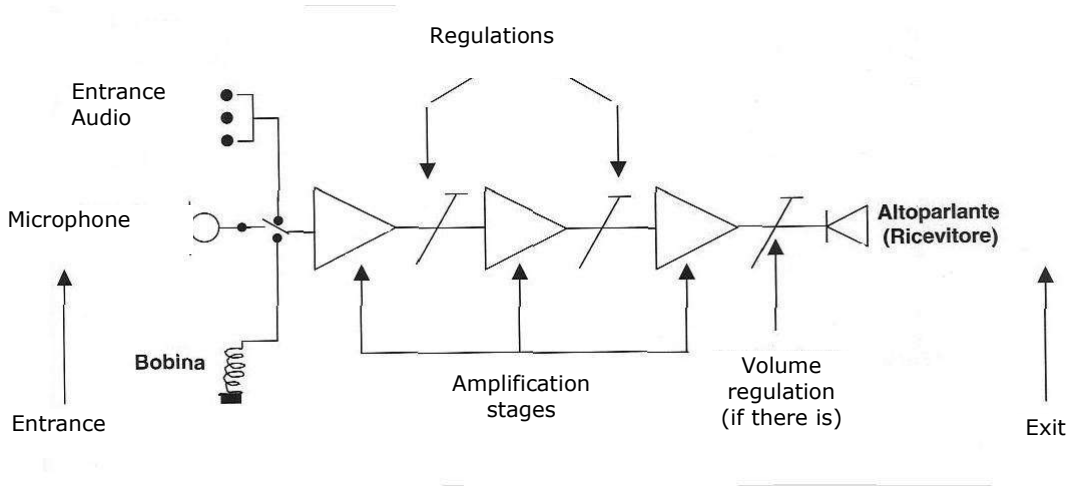
In synthesis these are the digital hearing aid gifts:
- reduction of typical lacks of traditional hearing aid as whistle, rumble, over-amplification of loud sounds;

- the best fitness on auditory user exigencies;
- the best quality of sound reproduction and complete programmability-again with new software versions;
- hearing aid models available: retro-auricular, mini-retro-auricular, endo-auricular and peri-tympanic.

NB the world trend sees the progressive diffusion of digital hearing aid that will substitute in few years the traditional and digitally programmable devices.

Auditory hearing aid: functioning principles

Apart from used technology (digital or analogical), the auditory hearing aid is made by three elements: the microphone, the amplifier- elaborator and the loud-speaker, called receiver.
Digital hearing aid have a further circuit that, after the microphone, transform the sound in digital impulse to elaborate and, in analogical way, it transforms it again in sound to send out to receiver and so to tympanum.
The hearing aid is fed by a little battery Zinc-air type expressly studied for auditory hearing aid, easy to change and during from 5 to 15 days. The auditory hearing aid has a lever commutator or switch with the following positions: O off, M microphone on, T telephone coil on. The position T excludes or chokes the microphone and inserts the telephone coil that helps the phone conversation (only in fix telephone network not in mobile phone and cordless) and ameliorate the hearing in cinema or church arranged beforehand with magnetic field.
A second control manoeuvrable by the patient is the little roller of volume; this is only in linear hearing aid of power usually retro-auricular, in some hearing aid with a little push-button or distant control is possible to change the hearing program better adapting to particular conditions as to listen to music.
Auditory hearing aid are adaptable to the auditory patient's loss; the audiohearing aidt regulates the yield of the hearing aid using a computer and a dedicated software. In the easiest auditory analogical hearing aid the regulation is acted using screw of control miniaturized (trimmer) placed in a not accessible zone fir the patient or hidden by a little wing.
Using a block system, it's possible to represent the elementary circuit of auditory hearing aid in way showed in the following figure.



This is the same also in most advanced hearing aid even if , in this case, the circuits are virtual, result of software.

The microphone receives sonorous waves and transforms their in electric signal; this signal, elaborated and amplified by the amplifier, is transformed in sonorous signal by the receiver and then transmitted to the tympanum membrane.

Microphone

The microphone transforms the sonorous waves in electric signal. The sonorous waves, succession of compression and rarefaction of air molecules, hit the microphone membrane inducing the vibration. The membrane is a paper really thin made in light material; the quality of the microphone dispends on membrane and on easiness with which it hurls. The membrane is rigidly linked to the transductor, that transforms sonorous vibrations monitored by the microphone membrane in electric signal. The fidelity of sonorous reproduction of the microphone is high with response in linear frequency from 100 to 8000 Hz.
Some hearing aid gets on two microphones that, working in couple, assure a direct (direttivo) hearing. Direct (direttivo) microphone, instead of ominidirectional ones, privilege the reproduction of sound frontal coming; direct microphone ameliorates the hearing in noising environments as restaurants an crowded meetings and reproduces in part the natural direction of human ear.

Telephonic coil – audio entrance

Besides microphone, some auditory hearing aid (generally the retro-auricolar ones) can receive magnetic signals from telephonic coil and electric signals from audio entrance. The telephonic coil picks up magnetic field made by receiver of fix network and amplifies it. The commutator in T position puts into action the telephonic coil and contemporary excludes the microphone; doing so the auditory hearing aid amplifies the only telephone signal, eliminating possible environmental noises of trouble. The telephonic coil could be used with vantages also in environments with environmental magnetic field as some cinemas or churches. The telephonic coil in high quality hearing aid guarantees a loud and clear signal and it's available on some endo-auricular hearing aid too.
Some hearing aid have a commutator with intermediate position MT that limits, but doesn't exclude the microphone; this assures the perception of environmental noises and ameliorates the acquisition of telephonic signal.
The use of a telephonic coil is very useful but it's necessary a profound counselling of the patient who, if ancient, will have same starting difficulties in the button use and of correct position of receiver.
Audio entrance is present only in retro-auricular hearing aid and allows the direct link from sonorous source (tv, radio, extern microphone) through an electric cable or a device without wires, to the auditory hearing aid. This contrivance reduces the environmental noise influence to advantage of vocal discrimination; through the audio entrance are used FM systems for the hearing in scholar sphere.

Exit electro-acoustic transductor of (receiver)

The receiver has the duty to transform electric signal elaborated and amplified by the amplifier of the auditory hearing aid in a sonorous signal using by human ear. The receiver is a component of delicate auditory hearing aid and, in endo-auricular hearing aid, it's protected by an adequate para-earwax. As an loud-speaker in miniature, the receiver is made by a coil, a magneto and by a thin membrane like that of microphone. When the coil is covered by sonorous electric signal it hurls and with its hurls the membrane too, generating the sound.
For its reduced size (only few millimetres as to centimetres of loud-speakers of radio and tv) the hearing aid receiver is subject to some limitations. The auditory yield of the receiver is

characterized by resonance peaks that alternates the sonorous quality of the hearing aid; furthermore even if in little percentages the receiver makes harmonic distortion and intermodulation. An other fault of the receivers is the distortion of transitor, that alters the auditory features of word that appears altered in semantic content.
In some case the yield of a microphone or receiver could be varied by auditory interventions as changing with the length and diameter of the tube in the hearing aid or intervening on little curve of retro-auricular hearing aid with auditory filters.

Osseous vibrator

The principle of functioning of osseous vibrator is like the receiver's one; in this case too the sonorous electric signal, amplified by the amplifier, induces in vibration a coil linked to vibrator structure. The vibrator makes sonorous levels limited in a restricted frequency band and it's used in transmissive deafness.
Hearing aid that use the osseous receiver are the osseous glasses and hearing aid by box with bow used in deafness due to a malformation of external and medium ear and the semi-installing BAHA hearing aid.

Amplifier- elaborator

It's reducing to think that an auditory hearing aid is limited to amplify sounds; in truth, besides sounds potentiation, the auditory hearing aid has elaboration and control circuits of sonorous signal, that allow to really adapt the electroacoustic features of hearing aid to patient's deafness. Today, with the most modern digital hearing aid, is opportune to speak more than amplifier of units about sounds elaboration and adaptation of hearing exigencies of the patient.
The electric "heart" of auditory hearing aid is made by digital elaborator that in 3 millisecond about decomposes, models and amplifies sounds.
Simplifying, to better understand the principles of functioning, in a digital hearing aid it's possible identify: amplifier, filters, compression circuit of dynamic and limitation of maxima exit, reduction circuits of environmental noise and the whistle suppressor (anti feedback).
The task of the amplifier is substantially to increase the sonorous signal received by the microphone. The parameters that define an amplifier are the gain, the maxima exit and the curves of entrance/exit; through these values it's possible to verify the efficiency of auditory device as we will see in the next chapters. With gain we mean the difference of sonorous level, expresses in decibel (dB), between the entrance signal and the exit of hearing aid; the gain is noticed, for international treaty, with entrance signal of 50 or 60 dB SPL.
The maxima exit expresses the maximum sonorous level distributable by auditory hearing aid in condition of saturation; always for international treaty, the maxima exit is noticed with an entrance signal of 90 dB SPL.
The most powerful are able to reach a gain from 70 dB to 1000Hz and more of 140 dB SPL of the maxima exit.
The entrance-exit curve links the sonorous level of entrance, monitored by the microphone to that amplified in exit by the receiver; the course of entrance-exit curve expresses the gain of auditory hearing aid in function of sonorous level of entrance signal.
In the following figure, are pointed on abscissa (horizontal axis) the entrance values in dB SPL, on vertical axis of ordinate the levels, always in dB SPL, relatives to the exit.
Observing the curve course, it's possible to notice as to a sonorous level X of entrance corresponds an amplified exit level of X+gain; if, for example, the level of entrance signal to the hearing aid is of 55 dB and the hearing aid gain is of 20 dB, the amplified exit will be of 55+20= 75 dB.
The gain values could be fixed and in this case it's possible to speak about hearing aid by linear amplification (constant gain for feeble, medium and medium-loud sounds) or variable

amplification in function of the entrance signal for not linear hearing aid or WDRC (decreasing gain to the increasing of sound in entrance). Besides 80 – 90 dB of entrance in any case in all kind of hearing aid, the amplifier arrives at maximum, it isn't able to maintain the gain constant and it "saturates". The audiohearing aid selects the auditory hearing aid gain acting on amplifier controls of feeble, medium and loud sounds and on maxim exit.
Sonorous signal besides being amplified is elaborated by filters, by the compressor of dynamic (AGC from English Automatic Gain Control) or by the limiter of maximum exit, by the noises suppressors and by the anti feedback system.
Particularly, filters act on sound, subduing some frequency bands; the AGC circuit modifies the dynamic of the signal reducing it and limiting the maximum exit; the noise suppressors start when there are some environmental noises and they reduce theirs interference on speaking message, the feedback control starts its action when it's necessary annulling with the same sound but controphase or through very precise filters.

Filters

Not always the entrance signal can be amplified and proposed again with vantage to patient's ear simply with increasing volume; for example in ski slope in which the audiometric loss is more important on medium-high frequencies from 1000Hz to more it's opportune to filtrate the medium heavy frequencies that, if normally amplified, yields not acceptable the hearing aid amplification.
The filtering is also used to ameliorate the hearing in noising environment as restaurants, meeting-halls, industrial laboratories. Filters are placed in analogical hearing aid between microphone and amplifier instead of in digital they are virtual circuits made by a numerical elaborator.
Filters are characterized by band and by attenuation. Band means the frequency range that is filtrate; there are digital filter really selective, with very thigh band. The attenuation shows how the filter can attenuate sounds in the band. Practically the filter attenuates only the part of the sound inside the band leaving unaltered the remainders.

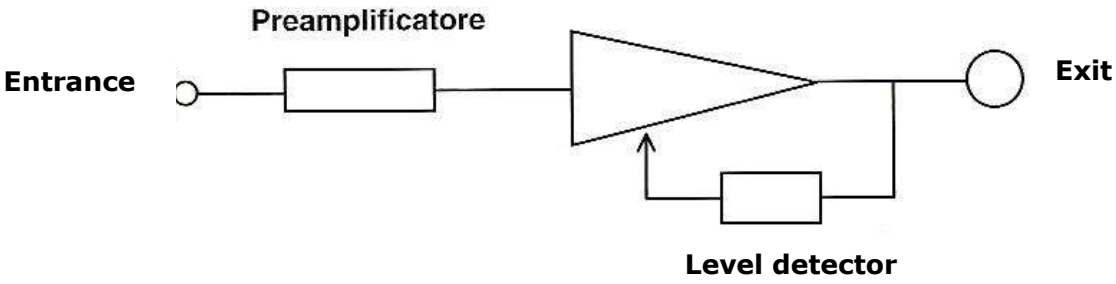
NB Without going into digital filtering theory, the most advanced auditory digital hearing aid filters can attenuate, according to audiologic exigencies , high or medium or heavy sounds without decay of sonorous quality. Referring to auditory digital hearing aid it's possible to loss himself in "channels" or "bands" searching the most endowed device. Actually even if the number of channels or bands is an important indicator of hearing aid adaptability, other parameters, often unknown, are able to influence the hearing aid yield in major measure than numbers of channels. We think only of elaboration speed that can induce delays of 5-6 milliseconds with a troublesome reduction of sonorous quality or of sampling frequency mathematically linked to band width, of the same hearing aid (furthermore today it's better in the analogical ones), of dynamic in sound amplitude or of background noise of the elaborator…

Amelioration of hearing in noise

The development of digital hearing aid has been accompanied by the circuits development to ameliorate the hearing of words in noise and the use comfort. We have circuits that recognized the word and ameliorate the comfort (voice finder), increasing circuits of "contrast" of voice (spectral enhancement) or circuits that automatically vary the response in frequency of auditory hearing aid in hearing conditions perturbed by environmental troubles. The aim of these circuits is that to yield easier verbal communications in critic situations of hearing, but sometimes this devices aren't able to operate an efficacious selection between voice to amplify and noise to subdue. In this case it's necessary resort to direct (direttivi) intelligent

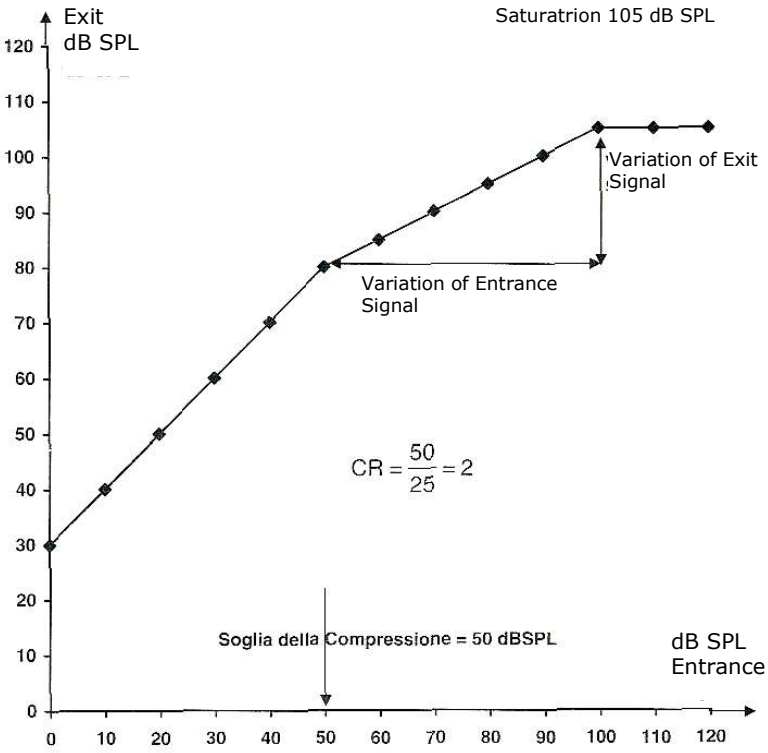
microphones, that are able to automatically orientate the listening towards the interlocutor reducing troubles coming from the back or at side of the listener. Direct (direttivi) intelligent microphones are available in retro-auricular hearing aid but also in endo-auricular ones.

Compressor circuit of dynamic



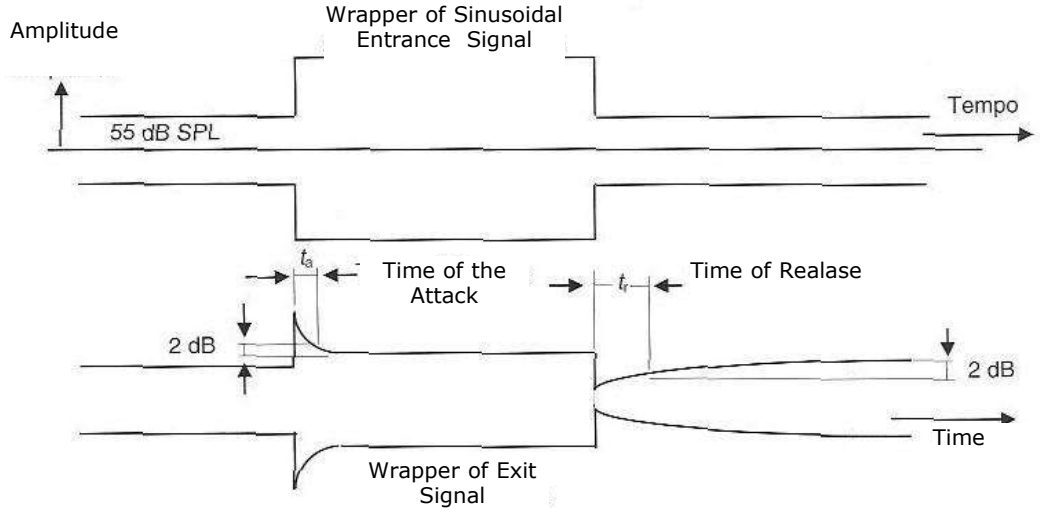
The plan of a compressor circuit of dynamic

The dynamic field of human voice is, in normal conditions, of 40-50 dB; it means that a normal speaker can pass from 30 dB of the whisper to 70-80 dB of loud voice.
The auditory threshold of a norm-auditory (normoudente) subject is of 0 dB HL, the pain threshold is reached by sounds of 120-130 dB HL; the dynamic filed of healthy ear is so of 120-130 dB HL.
Hearing loss causes the reduction of dynamic field of listening and this occurs because of the audiometric threshold increasing (deafness) and the pain threshold fall (recruitment).
In neuro-sensorial deafness the listening dynamic can be of only 35-40 dB; in this case the auditory hearing aid has to be by not linear amplification with AGC (or compression) to control the gain of the amplifier avoiding to amplify loud sounds that go beyond trouble threshold.
The hearing aid with compression are not linear instead of the linear ones use a limiter in the maximum exit to reduce loud sounds. The limiter of maximum exit alters the sound and can introduce the distortion.
In not linear hearing aid is possible to regulate what has to be the action of AGC simply changing the amplification of loud sounds (80 dB) as to that of medium sounds (65 dB) or soft sounds (40 dB); in this way we intervene on the relation of compression.



The graph shows the course of signal amplified (vertical axis) referred to entrance intensity (horizontal axis). It's important to note the effect of compression on reduction of amplify in exit for in entrance signals superior to 50 dB.

The compressor of dynamic are characterized by the time of attack and release. The time of attack time expresses, in milliseconds, the delay between the trouble and the instant in which the AGC goes into action reducing the gain of the amplifier; generally this delay is between 3 and 10 ms. At the end of the delay the amplifier progressively recovers the sensibility in 10 ms – 1500 ms. The time of release is important to plan the comfort and the precision of voice reproduction of auditory device and, in some devices, it can be adjustable.



On the top the entrance signal, on the bottom the signal amplified, it's important to note the delay induced by the compression.

Verify of auditory hearing aid

To verifying the hearing aid regulation or its well functioning, the audiohearing aidt uses:

1. empiric tests useful to verify coarsely at least the hearing aid, achievable with simple auditory instruments (stethoscope);
2. instrument made in measure (electronic ear and measurer of insertion/connection gain REM).

The empiric method needs easy and cheap instruments; this procedure of test, for its easiness execution, supplies useful maximum information and it's always advised by the audiohearing aidt and it can be executed for a first control by the logopaedist or by parents.

Empiric method

It's necessary to verify the battery charge with a special measurer; the normal voltmeter or tester aren't able to measure the battery charge!
With the battery charged, it's necessary to take in hands the device on to cup one's hand: the hearing aid, if it functions, emits a continuous whistle (auditory feedback of Larsen effect). When there isn't the whistle probably the hearing aid has some problems; it should be:

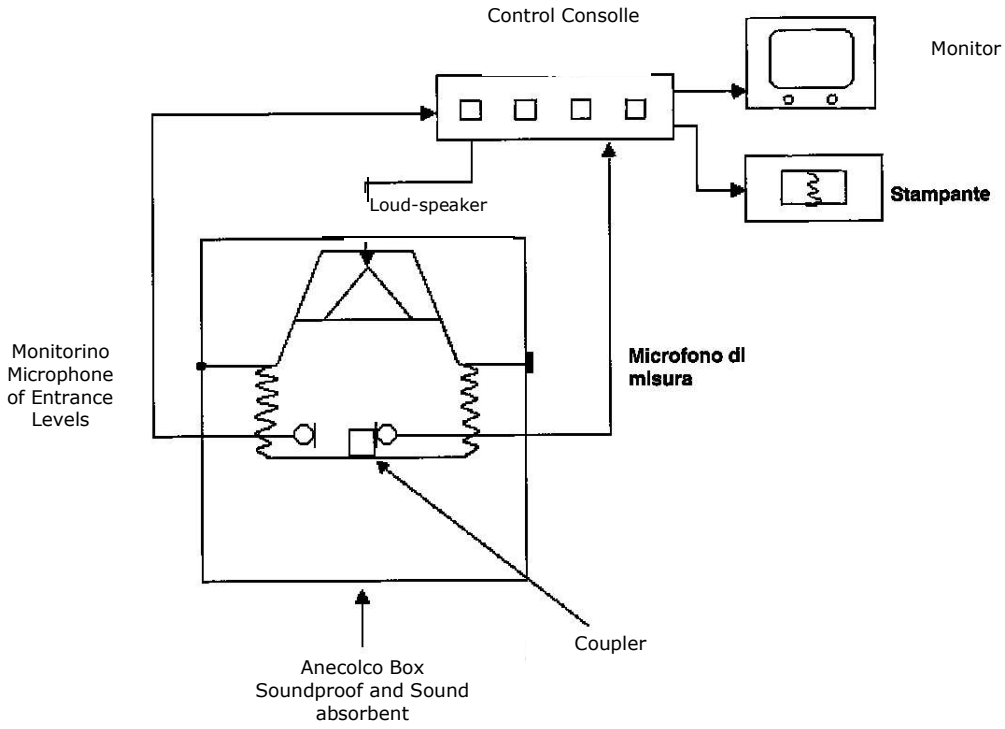
- battery off;
- receiver or microphone clogged or broken off;
- commutator of lighting or battery-career faulty;
- volume roller (if there is) broken;
- circuit damaged.

However, even if the hearing aid whistles, it's not said that its functioning is regular.
The stethoscope doesn't allow to value technical parameters of hearing aid but it supplies further useful information on hearing aid efficiency. A sonorous croaking reproduction is synonymous of high distortion of the receiver or the amplifier instead of a choked voice yield could show problems on the microphone or an earwax cloggage of receiver. These manoeuvres could be daily effected also by the same user or by parents or logopaedist. For a reliable check it's necessary the intervention of an audiohearing aidt and the use of electric ear.

Instrumental methodology

Instrumentally verifying an auditory hearing aid means to subject to electroacoustic tests and to compare data obtained to which furnished by the maker; the hearing aid that correctly function respects values indicate by building house.
To effect this analysis it's necessary to use electric ear. This device has an coupler that stimulates human ear to which is linked the auditory hearing aid to test. During the technical verify the auditory hearing aid is regulated in standard conditions describe by technical rules and planning by software in digital hearing aid as, for example:
Maximum amplification, compressor of dynamic disconnected, suppressors of noise or anti-feedback defused, passing band maxima (banda passante massima).
In these conditions it's possible to value the gain, the maxima exit, the harmonic distortion. The gain shows the hearing aid amplification of entrance sound; the gain is calculated subtracting from amplified sonorous level of hearing aid the entrance sonorous level. The

mathematic formula for gain calculus (G) is: G=U-I, where U is the sound level in exit by the hearing aid, I the sound level in entrance, during the test it's 50 or 60 dB SPL. 60 dB SPL correspond to medium sonorous level of voice in conversation; the gain is measured at least from 250 to 8000 Hz.



Simplifying plan of an electrical ear

With entrance of 90 dB SPL, the hearing aid delivers the maximal amplification and arrives to the maximum exit level; for maximum exit we consider frequency band includes between 150 and 8000 Hz.
With the distortion happens the fidelity of sonorous reproduction.
Are considered acceptable harmonic distortions not superior to 1-2%; the harmonic distortion is valued with sinusoidal signal of 70 dB SPL and auditory hearing aid in standard conditions.

Choice and regulation of auditory hearing aid

Preliminary exams

The ipoacustic patient who wants to use auditory hearing aid, is subjected to audiometric exams and questionnaires for the choice of hearing aid. The exams are: tonal and vocal audiometric exam, ipendenzometric exam, acoustic otoemissions and auditory evoked potentials above all in babies' deafness. The audiometric tonal exams aim to identify the auditory threshold and pain threshold that shows sonorous level considered intolerable in short period too. This is revealed in objective and subjective way. The subjective method consists in presenting sonorous stimula growing up to arrive to an intolerable level for the patient. The objective measure uses the stapedial reflex threshold. The searching of the level of trouble is always useful in neurosensorial deafness accompany to recruitment; the

association hearing loss-recruitment causes an important reduction of dynamic range that can pass from usual 120 dB to 35-40 dB about. In case of limited dynamic range, the audiohearing aidt selects a not linear auditory hearing aid.
Vocal audiometry besides the exam in earphones provides for an exam in free field with loud-speaker placed in front of patient to head and a metre distant. The examiner repeats disyllabic words grouped in lists of 10; besides disyllabic words (the most analyzed) are used logotomi (ex:asa, aka,apa, etc) and sentences.
Words lists are presented before in noise lack masking with decreasing sonorous level from 80 to 40 dB, than with masking noise and relation signal/ trouble of 10,0 and -10.
Both acoustic otoemissions that supply useful information on nervous cells functionality of internal ear, and auditory evoked potentials that inquire the efficiency of auditory nerve, complete the audiometric research at point of being the only objective exams available for the classification of infant deafness.
Finished the instrumental exams, there is the subjective analysis of patient's life and work habits, of his exigencies and expectations of hearing aid therapy. For this aim are used interview techniques by open question and we try to classify the answers with the use of questionnaires as COSI, Ventry test, etc.
This stage isn't less important of the previous one and needs specific knowledge of interview techniques and availability to create an emphatic relationship with the patient. Besides it's in this stage that starts the work of information and suggestion to the patient (counselling).
The answer to questionnaires and to interview supply apart from the age, an indispensable information about choice and regulation of the auditory hearing aid.
At the end of audiometric instrumental inquiry and of analysis of subjective aspects, the specialist, after audiohearing aid consult, has the task of planning the opportune therapy that should be chirurgical, medical or the application of an auditory aid as auditory hearing aid, semi-installing hearing aid or cochlear implant. Is the audiohearing aid, as for being the only qualified personage about it, the choice of the model, the application and regulation of external hearing aid, of the installed-ones and the regulation (mapping) of cochlear implants.

Adapting methods of auditory hearing aid

The selection of auditory device is made starting from audiometric exams and from theirs elaboration with mathematic formulas.
Through these prescription formulas of hearing aid gain, it's possible calculate the ideal auditory gain for hearing loss in exam and so choose the fittest auditory hearing aid.
In the choice and in hearing aid adaptation have to be considered in the same way the aspects underline in subjective analysis as: age, hearing motivation, frequented environment, occupation, life habit. For example in a young patient who actively works or who however spends his life in relationships in noising environment too, as conference hall, restaurants, etc, he has hearing exigencies different from elderly pensioner who mostly lives at home. The type of hearing aid (retro-auricular, endo-auricular, osseous glass) is chosen on the basis of above listed parameters: as general rule the osseous glass and semi-installed BAHA hearing aid are kept for transmitted deafness; all ipoacusie can be prosthesized by retro-auricular devices and by endo-auricular hearing aid, important and heavy deafness and infant deafness need retro-auricular hearing aid.
Among numerous prescription forms of hearing aid gain it's possible to recommend: rule POGO(Prescription of Gain Output) for heavy deafness, rule NAL (National Acustic Laboratories Australia), rule for medium deafness, rule DSL (Desired Sensation Level) for infant deafness. The table summarizes the calculus methodology of insertion gain (so to the level of tympanic membrane) for rules NAL (as said above)and POGO 2.

$$Gi = X + 0{,}31 \bullet HL + K + PC$$
$$X = 0{,}15 \bullet HLmedia + 0{,}2 \bullet (HLmedia - 60)$$

PC è un ulteriore fattore correttivo (oltre a K) funzione sia della frequenza che dell'entità della perdita uditiva tonale a 2000 Hz, come descritto dalla tabella seguente:

Frequenze (Hz)

Perdita a 2000 Hz dB HL	250	500	1 K	2K	3K	4K	6K
≤ 90	0	0	0	0	0	0	0
95	4	3	0	- 2	- 2	- 2	- 2
100	6	4	0	- 3	- 3	- 3	- 3
105	8	5	0	- 5	- 5	- 5	- 5
110	11	7	0	- 6	- 6	- 6	- 6
115	13	8	0	- 8	- 8	- 8	- 8
120	15	9	0	- 9	- 9	- 9	- 9

Values of PC in function of frequencies and of loss to 2000 Hz

POGO 2:

Insertion gain = HL/2 + C1 + C2

	Hz	C1
	250	-10
	500	-5
over	500	0

HL	C2
≤ 65	0
> 65	(HL-65)/2

In addition to prescription rules above-listed the producers of auditory devices have elaborated regulating methods for digital not linear hearing aid that makes allowance for, besides audiomentrist, also of the age and users' life factors. The software of regulation of each model automatically estimates the best regulation of hearing aid and maxima exit too that have not to reach the pain threshold; if it's known stapedial reflex threshold, the maxima exit of hearing aid haven't to overcame it with more than 7-10 dB. After having apply the hearing aid it's recommended to value and eventually correct the effective gain supplied by the device through the measure in situ of amplification (Real Ear Measurament REM).
The hearing aid is well choose and regulated if the requested gain is to 2/3 of maxima amplification.
Arrive to the ideal gain, the audiohearing aidt has to verify that the hearing aid yield by means vocal test in free field. The obtained vocal threshold could be compared with which by free ear; the hearing aid yield is satisfactory if the patient is able to discriminate the majority of words supplied to sonorous level of 60-50 dB, as the level of conversation voice and with a relation signal/noise of +5 +10.
These values change with the audiometric loss and the kind of deafness; on this subject are critic the neurosensorial retro-cochlear deafness, in which, to real hearing loss, is added a reduction of discriminated capabilities: the patient listens but he isn't able to understand the meaning of the words.

So it's opportune subject the patient, with worn hearing aid, to hearing aid tolerability test acted with pure tones, band noise, sonorous instrument of AMBO suitcase. Besides consider patient's subjective impressions, the audiohearing aid, during tolerability tests, has to value the presence of unintentional reflexes (for ex. Cochleopalpebral) objective indicators of auditory trouble and if it's necessary reduce the maxima exit. It's possible to reach the hearing aid fitting intervening contemporary on hearing aid regulation and on acoustic of retro-auricular cochlea or of the endo-auricular hearing aid shell. It's indispensable to ask to patient questions that could show hearing problems with the hearing aid, unpleasant or excessive sounds. It's important to check, if it results perceptible the so-called occlusion effect provoked by the closing of the duct.
Occlusion effect makes unpleasant for the patient to listen his own voice that is perceived thundering, the occlusion effect is reducible increasing the ventilation of hearing aid.
This is only the starting point of delicate process of hearing aid fitting that needs professional competence, experience, patience and empathy of the audiohearing aidt towards the patient. This stage could be repeated more and more during the hearing aid fitting that could need several mouths. In fact the fitting process has necessary to be gradual to allow to the patient the progressive tolerance of forgotten sounds. The application of auditory aid allows the stimulation of nervous centres and auditory areas of cerebral cortex perhaps unused by years because of deafness. In this case it's possible to speak of cerebral plasticity. The auditory stimulation makes in general possible a good recovery of auditory ways functionality but only giving adequate time to the process.

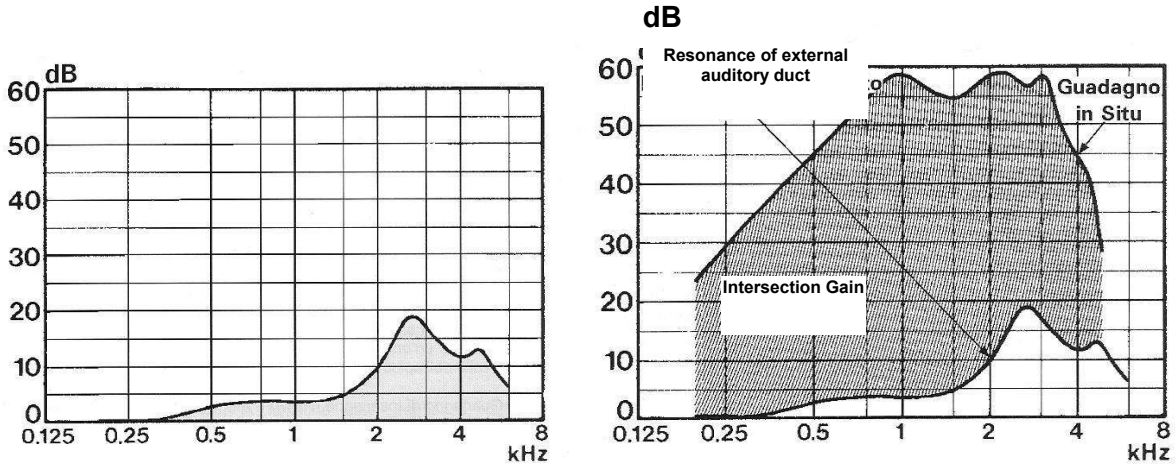
Counselling and rehabilitative therapy

In the fitting stage the audiohearing aidt holds a basic role not only because he's responsible of the choice and regulation of auditory device but also for the activity of information and suggestion to the patient (counselling) that starts till the first contact with the user. The patient has to be informed about qualities and lacks of auditory aid, on modalities and developing times of fitting and, not least, on expectations reasonably compatible on type and grade of deafness. Furthermore with the counselling is possible to resolve small problems like the change of the battery, the cleaning of para-cerumen, the servicing, the application modalities of the device. The counselling is flanked the logopaedic rehabilitation in infant deafness and many other applications in adult users.

Valuation of hearing aid gain

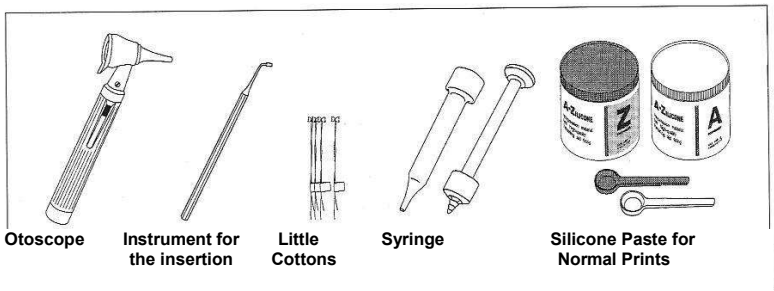
The gain supplied by the hearing aid can be measured as functional gain (hearing aid yield) or gain of REM insertion.
To measure functional gain it's necessary to point out the patient's audiometric threshold to bare ear and with hearing aid worn. The difference between the threshold with and without hearing aid represents the functional gain. About us the easiness of test execution makes it optimum in the valuation of hearing aid yield of infant deafness; however the measure supplies a quantitative value coarse enough for which the effective yield has to be integrated with the parent's and logopaedist valuations of response to real life and to rehabilitative therapy.
The measure of the insertion gain is more precise, it is the difference of sonorous level measured closeness to tympanum with and without auditory hearing aid through a thin tube to place closeness to tympanum. The insertion gain needs the valuation of the resonance of the duct to free ear. This depends on anatomic conformation of the ear, and it's characterized by

a peak of 20-25 dB on high frequencies (2000-3000 Hz). With the introduction of the hearing aid the duct is obstructed and the “free” amplification due to the resonance of open ear is lost. The audiohearing aidt inserts the hearing aid without moving the little tube and he repeats the measure. With this procedure is possible to measure the real gain of the hearing aid, said insertion gain. The insertion gain is placed subtracting to sonorous level, measured closeness to the tympanum by the little tube with hearing aid worn the sonorous level always closeness to tympanum but with ear without hearing aid. The measure of REM needs the collaboration of the patient and so it isn’t usable in infant applications. In this case it’s possible to opt for a simplify procedure of REM said RECD (Real Ear Coupler Difference) that needs a certain collaboration of the baby.



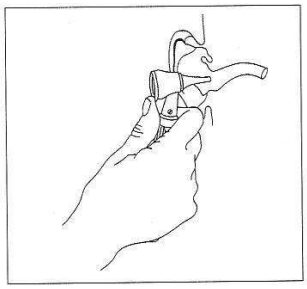
On the left the resonance curve of open ear without hearing aid, on the right it’s possible to note as the insertion gain is the amplification of hearing aid minus the natural resonance of open ear.

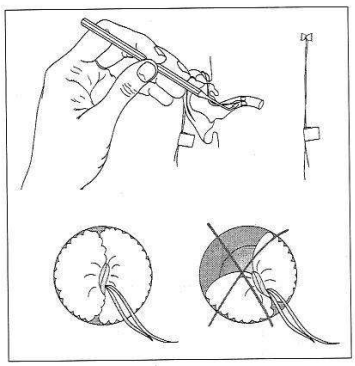
The taking of the auricular print



Before all the audiohearing aidt has to carry out a rapid analysis of the auricular duct observing it through an otoscope in way of:

1. realise the dimension and the morphology of the duct;
2. exclude the presence of earwax, the presence of any kind of medium and/or external ear pathology ;
3. examine the form of the duct, in fact if ensues that it widens towards the tympanum or if it presents a very acute angle to the second curve, it’s not expedient the recording of deep prints.



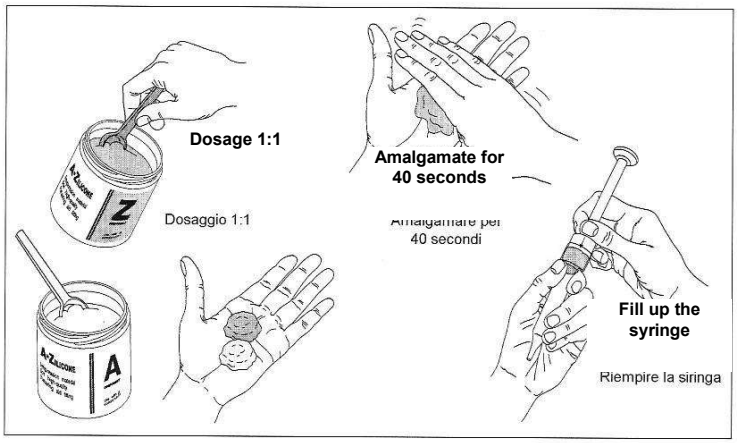


1°) examine the ear with an otoscope

How take an auricular print

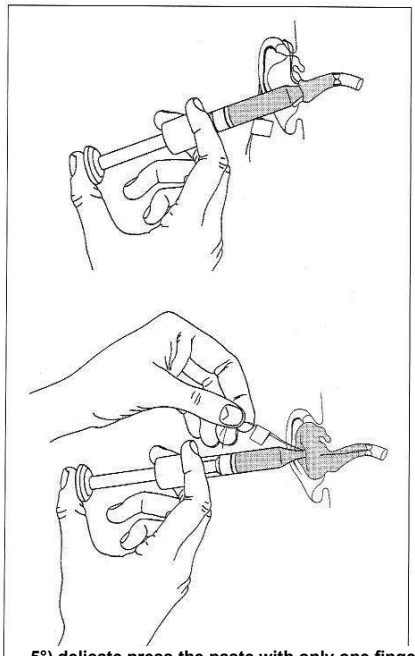
Instruments: otoscope, bright pen, little cottons, syringe and silicone paste.

Process:
→ examine the ear with an otoscope
→ insert the little cotton with the bright pen up to getting over the 2nd curve of auditory external duct and control with the otoscope that it has been correctly placed, in way to close completely the auditory duct.
→ prepare the silicone paste mixing the two pastes, the blue or green or yellow one and the white one in dose 1:1 and rapidly amalgamate. After that insert it in the syringe.
→ insert the syringe in the auditory external duct, placing the tip of the syringe to the bottom of the duct.
→ inject the paste, filling up the duct and the concha, gradually moving to the back the tip of the syringe. To avoid snags, as air bubble, it's expedient to maintain the tip of the syringe always immerse in the paste.
→ delicate press the paste with a finger and wait for the hardening time (5 minutes about).
→ remove the print, delicately drugging the lobe to the bottom and eventually ask to the patient to open his mouth to make easier the extraction.
→ Verify the print has both the first and the second curve and that there aren't missing pieces due to air bubbles and/or not enough paste.



3°) prepare the syringe with a tip with normal diameter, using silicone material of middle hardness for prints.

3º) Preparare la siringa, dotata di una punta di diametro normale, adoperando materiale per impronte siliconico di durezza media.



4º) Inserire la pasta siliconica nel condotto uditivo esterno. Prima di iniettare la pasta posizionare la punta della siringa in fondo al condotto uditivo.

Iniettare la pasta, riempiendo il condotto uditivo e la conca, muovendo lievemente e gradualmente indietro la punta della siringa. Per evitare bolle d'aria, è importante mantenere la punta della siringa sempre immersa nel materiale per impronte.

5°) delicate press the paste with only one finger and for only one time!

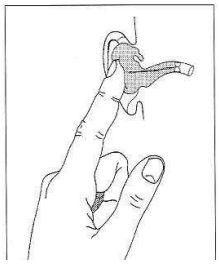
Wait the hardening time (6 minutes about, in dependence of temperature). Verify the complete hardening: pressing the paste with the nail it hasn't to remain any mark.

→ the prints have to be store up in rigid boxes that don't compress the same print to avoid modifies on morphology. Furthermore the prints have to be used in 15-30 days to avoid alteration phenomena of the form of the same print.

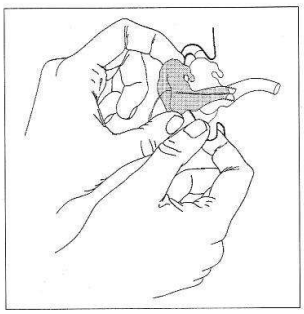
NB the patient during the placing of the little cotton could feel itch to the throat or feel short coughs. In this case the little cotton or the print "tickle" the vagal nerve (vagus) that sometimes has a course close to the duct. In these cases is better to extract the little cotton up to the disappearance of troubles.
In case of realization of endo-auricular devices it's better the realization of a second print for a major security and comparison in the execution.

5°) Premere la pasta delicatamente con un solo dito e per una sola volta!

Attendere il tempo di indurimento (circa 6 minuti, in dipendenza della temperatura). Verificare l'indurimento completo: spingendo sulla pasta con l'unghia non deve rimanere alcun segno.



6°) remove the print.



Delicately drug the lobe to the bottom to allow to air to find a course towards the duct, equalizing the pressure and making possible and easier the extraction of the print. Delicately remove the print doing a soft rotative movement.

pressione e rendendo la rimozione dell'impronta possibile e facile. Rimuovere l'impronta delicatamente eseguendo un leggero movimento rotatorio

Some illustrations come from : "L'adattamento degli apparecchi acustici" (" the adapting of auditory devices") Umberto Cotrona, Walter Livi ed. Oticon that we thank.