**Paparella: Volume II: Otology and Neuro-Otology**

**Section 2: Audiology**

# Chapter 10: Hearing Aids

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## What is a Hearing Aid?

The hearing aid has been defined in a number of ways, but basically it is any device capable of intensifying the sound reaching a person's ear or bringing a sound more effectively to that person's ear. The first hearing aid has been hypothesized to be as simple as a hand cupped behind the ear. This has not been documented but may well indeed have been the case. Other early hearing aids or sound-collecting devices consisted of widely known ear trumpets, which gather sound through a large trumpet-like end and funnel it through a progressively narrower passage to the ear. These provided advantage in some frequencies while sacrificing intensity at others. Other types of ear or sound collection devices were developed that were "hidden" in acoustic fans, chairs, and so on, indicating that an attempt was made to be as inconspicuous as possible about hearing loss.

The first electric hearing aids were introduced around the beginning of the 20th century and were in part attributed to Alexander Graham Bell's work that later resulted in the telephone. These early developments resulted in desktop hearing aids that were nonportable and were placed in an advantageous spot on a desk or table. Gradual reductions in size were made in these early carbon-type hearing aids, resulting in a unit that could be worn in a harness on the body accompanied by a fairly large battery pack. The overall sound quality of the early carbon hearing aids was fairly poor due to the crackling and hissing noises associated with the friction of the carbon granules necessary to produce the sound.

With the development of the vacuum tube, quality of hearing aids improved, but size once again increased because the vacuum tubes were quite large. About the mid-1930s, these tubes were reduced in size and again hearing aids could be manufactured in a size that would allow them to be worn "portably". Batteries, however, were still quite large and often required a separate harness. In the 1940s, developments in battery production were such that size could be reduced, thus allowing incorporation of batteries into the same casing as the hearing aid. The next real breakthrough came in the 1950s with the development of the transistor at Bell Laboratories. This led to the attrition of the transistor's precursor, and vacuum tube hearing aids virtually disappeared from the market. As the size of batteries continued to be reduced, transistors also allowed reduction in size of hearing aid components.

The 1960s brought the beginning of microminiaturization of amplifiers and other components for hearing aids, which again reduced the size of hearing aids considerably, allowing a greater degree of amplification in a smaller container. In the 1970s, more powerful hearing aids were developed that could be worn at the ear, in eyeglasses, and even in the ear. The 1980s have seen further developments and refinements in microminiaturization and reduction of chip size, leading to smaller and smaller hearing aids, some currently being work in the canal and behind the ear with greater and greater degrees of power. In the 1980s there

has also been a more pronounced move toward fitting patients with rather severe hearing loss with at-the-ear or in -the-ear hearing instruments as opposed to the previously used configurations on the body. For a more comprehensive historical background on the development of hearing aids, the reader is referred to a number of excellent perspectives (Berger, 1975; Carver, 1977, 1978).

## Types of Hearing Aids

Presently there are hundreds of different models of hearing aids available, ranging from group types, such as frequency-modulated (FM) or infrared listening devices and auditory trainers, implantable hearing aids, and cochlear implants, to wearable hearing aids such as body-aids, eyeglass-aids and at-the-ear, in-the-ear, and in-the-canal aids.

## Assistive Listening Devices

This rather broad category includes auditory training devices such as FM wireless systems used in classrooms; these have drastically improved the signal-to-noise ratio for the individual student. The instructor wears a portable microphone and the signal is transmitted via a wire loop placed around the circumference of the room and then channeled directly to the receivers worn by each student. Other popular devices include infrared systems, which have been used in meeting rooms and concert halls to transmit the acoustic signal by means of infrared beams of light. In this instance, a wireless receiver is worn by each recipient, who may adjust the receiver to the individual comfort level of loudness. Restrictions include the requirement that the receiver must be in the line of sight of the broadcasting module and within a certain maximum distance from the module (within 30 feet for smaller systems).

The less portable desktop hearing aids, or auditory trainers, are still used in many classroom and therapeutic situations. They are falling out of favor due to developments and refinements that allow increased power and fidelity with body-worn and head-worn hearing instruments.

Implantable hearing aids or hearing instruments, which have been used in Japan and elsewhere, use a piezoelectric output transducer technique in which a rod or piston is placed on the eardrum or attached to one of the ossicles. An external coil is driven with the output of the hearing aid amplifier and is placed in close proximity to the magnet for the best possible coupling. The implantation of the magnetic transducer is similar to certain cochlear implants in that it is a transdermal transmission of sound from an externally worn magnetic coil, which in turn will drive the crystal. Other implantable hearing aids have included either a percutaneous attachment or a bone vibrator affixed to the mastoid with a titanium screw. There is also currently on the market a similar device that is totally implanted beneath the skin, again utilizing transdermally transmitted signals by means of a magnetic coil. The implanted device is attached to the mastoid by a titanium screw.

There are certain restrictions with the use of these types of instruments in that the subject's sensorineural threshold must still be quite good. These have been used in situations where, for medical or surgical reasons, chronic middle ear condition would obviate the use of traditional techniques of amplification. While currently limited to adults who meet strict criteria for selection, these devices may soon be available for pediatric patients as well as for

those with unilateral sensorineural hearing loss. The next few years should bring some remarkable developments in the area of implantable hearing aids.

## Cochlear Implants

Cochlear implants have recently gained much interest, with as many as 11 devices currently in production; an excellent description of those implants available, as well as individual characteristics of the implant, appeared in the *Journal of The American Speech, Language, and Hearing Association* (ASHA, 1986). Currently there are six different implant configurations available in the USA, ranging from the single-channel, single-electrode 3M/House design to the multichannel, multielectrode configurations of the INER-AID/Symbion device from Utah and from Nucleus of Australia (Cochlear Corp).

In 1968 Dr William House produced the first cochlear implant. In 1983, it was submitted in conjunction with the 3M Corporation to the Food and Drug Administration (FDA) for approval. In October, 1984, it was approved for use in postlingually deafened adults and was thereby the first recommended substitution for one of the five senses. As of this writing, there are currently two approved devices for postlingually deafened adults: the 3M/House design and the Nucleus device from the Cochlear Corporation of Australia. In 1981, there were approximately 100 users of cochlear implants worldwide; in 1986, there were approximately 1200. Projections range up to 10.000 implantations by the year 1991.

The quest for a better and "smarter" cochlear implant has led many to conclude that "solving deafness is not easy". However, there is a population who do not view their deafness as a problem to be "solved" or a disease to be "cured", and who will remain resistant to attempts to solve their problem. The presence of this population may lower the projected numbers for possible candidates for implants.

Cochlear implants to date have been proven to enhance a person's ability to perceive environmental sounds and, in many instances, to improve the individual user's ability to lip-read. There have been some cases of improved performance in open-set discriminative ability for speech both with and without visual clues, which makes the future look quite promising for the further development of cochlear implants. However, thus far there has been only a limited attempt made at uniformity in determining the etiology and pathology of conditions found in users of implants, as well as at uniformity in methods of testing and in comparisons of the implanted devices.

Currently, the criteria for candidacy for cochlear implant include postlingually deafened adults of at least 18 years of age, who are obtaining no measurable benefit from amplification in either ear, either with or without the use of visual clues. Many also include the use of vibrotactile devices in their evaluations. The 3M/House and Nucleus/Cochlear designs have also been approved for experimental use in deaf children.

## Wearable Hearing Instruments

All electric hearing aids consist of the same basic components: (1) microphone, (2) amplifier, and (3) receiver. The microphone is a device that picks up sound and transmits it to the amplifier. Various types are available, ranging from those that are sensitive in a specific

frequency range to those with very flat amplifiers. The latter take the signal from the microphone and amplify or increase its voltage, are driven by a battery or batteries, and are controlled by potentiometers or controls for volume, tone, output, and so forth, so the signal can be transmitted to the receiver. This sends sound via the coupling device (eg, ear mold or tubing) to the ear. Following are the four basic divisions of wearable hearing instruments.

### Hearing Instruments Worn on the Body (Body-Aids)

Body-aids are powerful instruments that constitute less than 1 per cent of the current hearing-aid market (Mahon, 1986b). The primary purpose for having a body-worn hearing instrument is to separate the amplifier-and-microphone segment of the hearing aid from the receiver, in order to supply a great deal of power while reducing the annoyance of feedback. One application is monaural, in which the body-aid is used with a single cord to a single ear. Another application uses a "Y" cord. This is a pseudo-binaural situation in which a monaural signal is sent to each ear. A true binaural configuration would entail an instrument with two separate channels or wearing two separate body instruments and amplifying each ear individually. This type of configuration has in the past been used for very severe hearing losses, especially in children, and those patients who, for reasons of dexterity, are unable to manipulate the smaller controls on head-worn hearing instruments.

### Eyeglass-Mounted Hearing Aids

Eyeglass-mounted hearing aids, while once popular, have fallen out of favor and currently account for less than 1.5 per cent of the total hearing-aid market (Mahon, 1986a). In this type of configuration, the electrical components of an individual hearing aid are often mounted in the bow of the eyeglasses. There are also certain cases in which a behind-the-ear hearing aid may be adapted to the bow of eyeglasses. The former may be used in situations in which extreme high-frequency emphasis is needed or a CROS (contralateral routing of signal) configuration is needed, in which the microphone is mounted on one side of the head and the amplifier and receiver are located on the opposite side.

There are some inherent difficulties with eyeglass-mounted hearing aids. For one thing, if the glasses are laid down on a table or set in a pocket, the very thin wires used to connect the individual components are subject to breakage or dislocation. Another disadvantage is that when the person's glasses ("eyes") are removed, his "ears" are removed as well. In the past there has also been a limit to the various styles available for eyeglass-mounted hearing aids, due to the size of bows necessary. The advent of the eyeglass bow adaptor for behind-the-ear instruments has helped eliminate this problem to a great extent.

### At-the-Ear-Hearing Aids

The behind-the-ear type of at-the-ear hearing aids, while once the mainstay of the hearing industry, now makes up less than 40 per cent of the total market share (Mahon, 1986b). They have proved to be an extremely effective form of amplification, and highly reliable in that the individual units are assembled in precisely the same fashion for each of the model lines. At-the-ear hearing aids generally have a two-part configuration, with the hearing aid and a coupling device (earmold or tubing) needed to direct the sound to the ear. Earmolds come in a number of styles and configurations and are generally selected based

upon the person's needs for amplification and other individual needs (medical considerations may contraindicate a certain type of earmolds). A number of different modifications allow at-the-ear hearing aids to be adjusted by potentiometer for differences in emphasis by frequency, output, compression, and so forth. The earmolds may be modified for greater flexibility in fitting. Because of the two separate components, at-the-ear hearing aids are adaptable to a wide range of sounds and qualities for many patients.

## In-the-Ear and Canal-Type Hearing Aids

Within the past few years, in-the-ear hearing aids have become increasingly popular. They take up now the lion's share of the hearing aid market, with just under 58 per cent of total sales (Mahon, 1986b). In comparison with other types of hearing aids, in-the-ear hearing aids are relatively easy to fit and have been marketed with a great deal of emphasis on their cosmetic appeal. With further advances in the electrical circuitry, in-the-ear hearing has become very popular in that other, previously unavailable modifications are usable to further tailor the sound of the hearing aid to the individual's needs.

The smaller, canal-type of hearing aid is essentially an in-the-ear hearing aid that has been further miniaturized and placed into the canal portion of the ear rather than occupying the concha, helix and canal portions. Hearing aids became extremely popular with the much-publicized disclosure that President Reagan wore two of them. As is true with most of hearing aids, circuitry and operations of canal-type in-the-ear hearing aids have continued to improve with time, but these miniature hearing aids are still somewhat limited in application. Each manufacturer has a set of guidelines for appropriate fittings for the canal and hearing aid; primary considerations at this time appear to be (1) size of the canal, (2) power requirements for that hearing loss, and (3) dexterity of the individual user of the hearing aid. Due to the reduced size and thickness of the casing and the necessity for tightly packing the components and the battery compartment, the canal-type in-the-ear hearing aid often lends itself to fewer modifications on the part of the dispenser; this may, in turn, lead to more time and difficulty in tailoring the individual hearing aid precisely to the person's needs and comfort.

## Amplification: Terminology and Characteristics

Since the late 1950s, there have been a number of different attempts made to define standards for hearing aids and to report those standards' characteristics and specifications. The most current and widely used method of such description was compiled by the American National Standards Institute (ANSI) in 1976 (ANSI, 1976) with close cooperation between the federal government, audiologists, hearing aid manufacturers, and retailers of hearing aids. Such standards are necessary to ensure that (1) the specifications stated by the manufacturer are verifiable, and (2) meaningful information may be provided to the fitter of hearing aids in order to properly fit the individual. Following is a very brief summary description of ANSI standards.

1. *SSPL 90* (saturation sound pressure level) is a response obtained with a 90-dB input of sound pressure to the hearing instrument. In this particular instance, the hearing aid is tested with a 90-dB SPL pure-tone signal delivered to the microphone with the hearing aid's volume control set at full-on. It is graphically depicted from low to high frequency. (All measurements contained herein are performed on a standard 2-cc coupler as described by the

National Bureau of Standards.)

2. *HF average SSPL 90* (high-frequency average saturation sound pressure level) is a single number that averages the values for SSPL 90 at frequencies of 1000, 1600, and 2500 Hz.

3. *Full-on gain* is a response-curve obtained in a frequency-sweep fashion from the hearing aid with a 60-dB SPL pure-tone signal (50 dB for aids with automatic gain control (AGC)) used as input. The hearing aid is again turned full-on.

4. *HF average full-on gain* is similar to the above-mentioned HF average SSPL 90, with the exception that 60 dB is used as the input; again, averages of 1000 and 1600 and 2500 Hz are used.

5. *Frequency response curve:* The hearing aid in this particular instance is adjusted to a "reference test gain position". This represents the level at which the average of the SPL values at 1000, 1600, and 2500 Hz is 17 dB below that of the SSPL with an input signal of 60 dB. This is an attempt to establish some semblance of a "user setting" curve. Various calculations are undertaken with the resultant curve, and the frequency response from low to high frequency can be ascertained.

A number of other measurements are required by ANSI. These deal with drain on the current in the battery, harmonic distortion, equivalent input noise level, sensitivity of the telephone induction coil, and so forth; the requirements listed above were of primary interest in the actual fitting of a hearing aid. There are also a number of other terms used to describe various components of hearing aids; the reader is referred to Brunveld (1985) for further information.

## Audiology and Hearing Aid Evaluation

### What is an Audiologist?

An audiologist may be described as a nonmedical professional concerned with the identification of hearing loss and its management through rehabilitative devices and techniques. This includes audiometric evaluation and special testing concerning the auditory and vestibular system. The audiologist is also becoming an increasingly integral part of the dispensation of quality services and goods in the hearing-aid area of auditory rehabilitation.

The primary point of entry into the realm of hearing health care is through the medical field, with approximately 60 per cent of those receiving hearing aids indicating that they had first contacted their physician (Danhauer et al, 1985). The beginning journey to hearing aid use should preferably include the following: (1) audiometric examination with medical examination, preferably by an ear specialist; and (2) hearing aid evaluation and return visit to dispensing audiologist or hearing aid specialist for the fitting and follow-up. In recent years, the role of the audiologist has changed in this process in that more and more specialists in ear, nose and throat are dispensing hearing aids, taking the audiologist out of the prescriptive role and putting him or her in the working role of dealing with individual patients as a customer and helping the patient with hearing aid problems.

## Hearing Aid Evaluation

The hearing aid evaluation may consist of an earmold impression taken of the ear or ears in question; further testing may be done for uncomfortable levels of loudness and perhaps for discrimination of speech with and without noise in the background in order to establish which unit is best suited to the individual's loss. A number of aids may be tried in sound-field situations. Evaluation should include discussion of the types of hearing aids available for the individual's hearing loss and counseling regarding price and payment plans; counseling regarding expectations of the hearing aid user and of the family, if present; and expectations for the individual type of hearing aid.

The fitting generally follows the hearing-aid evaluation within two weeks and includes the actual fitting of the hearing aid(s), along with tests to ensure that the hearing aid is functioning up to expectations for the individual. These tests may include (1) traditional trial-and-error with pure-tone presentation through a sound field configuration, (2) testing for discrimination of speech in quiet and noisy situations (these being aided versus unaided situations), and (3) more recently popular real-ear measurements with pure-tone testing and possibly some adjunct speech testing. Further counseling is given at this time concerning the use and operation of the individual instrument, and warranties and insurance plans are also discussed. Possible problems and difficulties with the individual's hearing aid are covered. It may be advisable to have this information in written form because so much information is being presented to the hearing aid user at one time that it is often easy to overlook certain important aspects.

Follow-up generally occurs within the trial period (usually 30 to 60 days) and usually within the first weeks, at which time further counseling is given, if needed. The fit is tested, and further adjustments are made, if necessary; points of difficulty or questions raised by the individual are discussed at length. Follow-up from here may include having the patient return only if there are problems with the hearing aid or if he or she is encountering difficulties or having the patient return on a regular paid-for basis for aural rehabilitative classes and structured sessions.

## Real-Probe Micromeasurement

Certain instruments allow the audiologist/dispenser to monitor the sound delivered by the hearing aid to the person's eardrum, make given modifications to correct the patient's complaint, and not only listen to the change in frequency response but also see a graphic representation of changes in acoustic transmission at the eardrum. This alternative to an otherwise subjective procedure for fitting hearing aids is a more observable technique for fitting that takes some of the guesswork out of fitting and modification and gives the dispenser much more control over the fitting process. Other movements are afoot that put the hearing aid user in more direct control of what is being fit, by means of having the patient select that form of circuitry that is most pleasant and appropriate to the individual's listening situations. This is done primarily by trial-and-error, forced-choice methods.

## Who Is Benefited by Amplification?

Not so long ago, it was a widely held belief that the only real candidates to benefit from amplification were those with conductive hearing losses, the reasoning being that under those circumstances the cochlea was in fine working condition and therefore the hearing aid (the function of which is merely to receive sound and amplify that sound) was able to work quite well by overcoming this impairment in the conduction of sound. This is certainly true. However, the majority of persons who present themselves as candidates for amplification have sensorineural hearing loss, most probably due to the process of aging (Bebout, 1985). Sensorineural hearing losses have proved over time to be quite amenable to amplification in most cases.

Practical application and trial-and-error appear to show that, while hearing aids may not necessarily improve a person's ability to discriminate speech, the individual in question very often is able to hear speech at a level loud enough to reduce some of the strain of understanding in everyday situations. In other words, even individuals who don't have "good" discrimination scores may do well with amplification. In the past, a general rule of thumb was that a person was not really a candidate for amplification until hearing thresholds had reached the range of 30 to 40 dB. Recent practical application and studies have indicated that this is not necessarily the case, and that a great deal of benefit is derived from the use of proper selective amplification for people with near-normal, low- and mid-range hearing with a mild to precipitous drop in the high frequencies in one or both ears. Amplification also has been used for people with essentially normal hearing thresholds for the alleviation of chronic tinnitus.

## Applications of Hearing Instruments to Hearing Loss

Monaural versus binaural amplification has been a controversy for many years; it was previously believed that binaural amplification was acceptable if the ears were fairly symmetric in hearing loss. This is not a steadfast rule. Also, with advancements in hearing aid technology, it is often not necessary to use the larger, more cumbersome hearing aids for people with severely profound hearing loss; indeed, these individuals have been able to benefit from some of the more powerful behind-the-ear hearing instruments currently available and, in some cases, in-the-ear aids.

A brief mention of some special applications for hearing-aid fittings is in order. The first is in the CROS configuration (contralateral routing of signals), in which the microphone is on the patient's poorer/nonfunctioning ear, and the signal is received, routed to the opposite or good ear, and amplified to that ear. This may be used in situations in which the person has an essentially non-contributing ear on one side, and hearing thresholds essentially normal on the functioning side. The primary purpose is to give the person auditory balance and to eliminate the head-shadow effect.

A variation of this configuration is the Bi-CROS, which is intended for people with hearing loss in both ears, but with one ear that is essentially unaidable. The extra microphone is placed on the side of the unaidable ear, which would transmit sound to the "good ear" and receive amplification from the good side. This system provides amplification and reduces the head-shadow effect, as well (ie, the patient receives amplified sound from both ears, which

is directed to the "good" ear). An unaidable ear has been classified by Harford (1984) as "(a) an ear with complete loss or loss of such magnitude that amplification is not feasible, (b) an ear with speech discrimination ability too poor to benefit from amplification, (c) an ear in which medical problems contraindicate the use of the earmold, or (d) an ear with tolerance problem so marked as to preclude normal amplification".

Further variations on the CROS type of hearing aids include the power CROS, which is used when a person has one essentially unaidable ear and a moderate-to-severe hearing loss on the opposite side, the purpose being similar to that of a body-aid configuration that separates the microphone from the amplifier and receiver in order to reduce the probability of feedback at increased levels of volume. Another variation is the CRIS-CROS, which is a binaural power CROS. An IROS (ipsilateral routing of signals) configuration is basically an open earmold coupled to a conventional at-the-ear hearing aid or, more recently, to an in-the-ear hearing aid with very open fittings (ie, the use of a tube inserted into the ear canal, rather than the occluding portion of the hearing aid canal or earmold canal structure). Other variations on the CROS are available and espoused in the literature.

## FDA Regulations of Hearing Aids

In 1977, the FDA established regulations regarding labeling requirements and conditions for the sale of hearing aids. These regulations went into effect on August 25, 1977. Sections 801.420 and 801.421 of the Federal Food, Drug, and Cosmetic Act begin with *definitions of a hearing aid, ear specialist, audiologist, and dispenser* and indicate labeling requirements that the manufacturer/distributor must follow, including the manufacturer's name, model, serial number, year of manufacture, and so forth.

Guidelines are given for an instructional brochure which is to be offered to the patient prior to the signing of any statements by the potential purchaser. This brochure should be reviewed orally or in some form of communication with the potential purchaser and should contain information on how the hearing aid works; care and operation of the hearing aid; placement, insertion, and removal of the batteries; and how and where to obtain repair service. The brochure should list any harmful side effects that may require medical consultation (eg, accumulations of cerumen, possible skin irritation). Also, a statement should be included concerning the limitations of the hearing aid - for example, it will not restore normal hearing, and it is part of a total habilitation or rehabilitation program.

This brochure must also contain a section listing eight warning signs that the dispenser should be aware of, which would require medical intervention for the prospective purchaser:

1. Visible congenital or traumatic deformity of the ear.

2. History of active drainage from the ear within the previous ninety days.

3. History of sudden or rapidly progressive hearing loss within the previous ninety days.

4. Acute or chronic dizziness.

5. Unilateral hearing loss of a sudden or recent onset within the previous ninety days.

6. Audiometric air-bone gap equal to or greater than 15 dB at 500 Hz, 1000 Hz, and 2000 Hz.

7. Visible evidence of significant accumulation of cerumen or foreign body in the ear canal.

8. Pain or discomfort in the ear.

The brochure should also include some mention of the special criteria for fitting and selection of aids with total outputs of greater than 130 dB, and a warning of the possibility of incurring further hearing loss from the use of these high-powered instruments.

If the examining physician finds no medical contraindication for the use of a hearing aid, s/he will issue the following statement: "I have medically evaluated (patient's name)'s hearing loss, and this person may be considered a candidate for a hearing aid". The physician must sign this medical clearance form and date it, and a hearing aid cannot be sold without this statement. A waiver may be signed by fully informed adults (18 years of age or older), declining this medical evaluation for religious or other reasons. Records of these waivers must be kept in file by the individual dispenser for at least 3 years.

The evaluation procedure for children (under the age of 18 years) includes not only a physician's or medical intervention but also an audiologist's evaluation, because of the audiologist's training and experience in the evaluation and rehabilitation of children with hearing impairments. This evaluation can often lead to a referral for speech and language habilitation that may be the result of and concurrent with the hearing loss.

The dispenser of hearing aids must in no way encourage the individual prospective buyer to sign a waiver but must make it known to him or her that a medical evaluation for the hearing loss is in his or her best health interest. A person still wishing to sign the waiver must read and sign the following statement: "I have been advised by (dispenser's name) that the Food and Drug Administration has determined that my best health interest would be served if I had a medical evaluation by a licensed physician (preferably a physician who specializes in diseases of the ear) before purchasing a hearing aid. I do not wish a medical evaluation before purchasing a hearing aid".

The regulations also state that a copy of technical data for the individual hearing aid shall be furnished, either in a brochure or in a separate printout. This includes data as specified by ASA STD 7-1977, including SSPL 90, frequency response, high-frequency average SSPL 90, high-frequency average full-on gain, reference test gain, frequency range, total harmonic distortion, equivalent input noise, battery current drain, induction coil sensitivity on telephone coil aids, and input/output curve and attack/release times on aids with automatic gain control. Also, a copy of the user's instruction booklet or brochure provided by the manufacturer must accompany every hearing aid that is dispensed. This is intended to ensure that the individual purchaser will have provided a minimum amount of information about any given product. Additionally, most states (36 at last count) have licensure laws on their legislative books for audiologists and/or dispensers of hearing aids, again to ensure that

quality service is offered to the potential purchasers of hearing aids. In many states where licensure laws are not in effect, they are in the process of debate and approval/denial.

## Future Developments

Hearing aids have progressed from relatively simplistic mechanical devices to miniature, highly sophisticated, integrated electronic devices. Future developments are headed in a number of directions, including (1) "SMART" digital processing devices that can eliminate the distraction of background noise, reduce feedback, and improve speech-processing and that can be programmed/reprogrammed to an individual's needs; and (2) implantable hearing aids. Both types currently share some common obstacles, the primary one being the power source (battery). Digital processing devices require considerable power. The size of that power source may make them less readily accepted by the hard-of-hearing public.

Requirements for reduction of environmental background noise, reduction of feedback, and improvement of speech-processing by hearing aids have led manufacturers to a paradoxical point in which the search is for better and better circuits which in turn are larger and more sophisticated, contrary to the search for smaller, more cosmetically appealing instruments desired by the public. Thus far, some solutions available for the above problems have been directional microphones, binaural amplification (for relief by masking), and venting. Future possibilities include adaptive filters (there are several on the market), multichannel automatic gain control, and digital signal processing.

Another area of future growth is the area of cochlear implantation in children. Currently the House/3M single-channel electrode has been approved for investigational implantation in children. Implantable hearing aids share the problems of size and circuitry. What kind of power source can be implanted without danger and inconvenience to the user?

Two of the major turning points in the development of the digital signal-processing devices have been (1) the ability, with increased electronic advancements, to operate in "real time" by processing speech with remarkable speed and accuracy; and (2) the cost-effectiveness in being able to do this with a single chip, rather than a suitcase full of electronics. Most agree that within 5 to 10 years there should be something readily marketable. Other trends include increased use of real-ear measurement. In the last 3 years, the number of manufacturers of real-ear measurement devices has increased from one to nine, lending support to the idea that real-ear measurements will be a popular fitting method or adjunct in the future. Hearing aids, and their developers, are not static, and with increased understanding of and experimentation with current and future technologies, hearing aids will continue to get smaller and smarter.