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# An overview of hearing impairment in older adults: perspectives for rehabilitation with hearing aids

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**Abstract. – *Background:*** **Hearing loss is a common problem in modern society due to the combined effects of noise, aging, disease, and heredity. According to 2005 estimates by the World Health Organization (WHO), 278 million people worldwide have moderate to profound hearing loss in both ears. Incidence increases with age. Approximately 31.4% of people over age 65 have hearing loss and 40% to 50% of people 75 and older have a hearing loss. Only 1 out of 5 people who could benefit from a hearing aids actually wears one.**

***Objective:*** **To review literature for articles that focus on hearing aids.**

***State of the Art:*** **Hearing aids have continuously evolved over the past 50 years, in term of styles and technology. Technological advances in hearing aids and HATS (Hearing Assistive Technologies, and Rehabilitation Services) have expanded the range of options available to improve the success of a device use. Today's hearing aids differ significantly from their analog predecessors because the application of digital signal processing has permitted many adaptive and/or automatic features. Included in the benefits of digital hearing aids are improved sound quality, multiple listening programs for different listening environments, advanced noise reduction strategies, acoustic feedback reduction, compatibility with remote control options, and flexibility in manipulation of the frequency, compression, and gain.**

***Conclusions:*** **The hearing aids continue to be developed to enhance the characteristics in terms of rehabilitation and acceptability.**

*Key Words:*

Hearing Impairment, Hearing aids, Presbyacusis.

## Introduction

Hearing loss is a common problem in modern society due to the combined effects of noise, aging, disease, and heredity. Hearing is a complex sense involving both the sensitivity of the ear as well as the ability to understand speech. Determining the prevalence of hearing loss depends on the type and degree of the loss, the area(s) of abnormality in the auditory system (middle ear, inner ear, brain, e.g.), noise exposure, and age[1]. Mild losses may not be noticed and even moderate losses may not impose a problem for people with excellent perceptual abilities and good coping skills. Hearing loss may be defined by self-report, by report of friends and family, and by hearing testing. Formal audiometric testing is the gold standard for diagnosis and treatment monitoring. Testing may be done at any age. Formal audiometry provides relatively precise information displayed by frequency and hearing level. A convenient summary of the audiogram is the pure-tone average (PTA) of the cardinal speech frequencies (250, 500, 1000, 2000, 4000 and 8000 Hz). As the PTA increases, the hearing ability decreases. Normal hearing for speech is observed for people with PTAs of 25 dB or less. At a PTA of around 40 dB in both ears, most people are functionally handicapped and benefit from amplification. Severe to profound losses range from PTAs of 75 dB and greater. At this level, hearing aids provide limited benefit and consideration of cochlear implants is generally given. According to 2005 estimates by the World Health Organization (WHO), 278 million people worldwide have moderate to profound hearing loss in both ears[1]. 80% of deaf and hearing-impaired people live in low- and middle-income countries. The number of people worldwide with all levels of hearing impairment is rising mainly due to a growing global population and longer life expectancies. Incidence increases with age. Approximately 31,4% of people over age 65

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have hearing loss and 40 to 50 percent of people 75 and older have a hearing loss. Only 1 out of 5 people who could benefit from a hearing aid actually wears one[1].

Modern technology offers individuals with hearing loss options for rehabilitation and assistance with hearing. There are many types of hearing technologies, the main difference is in the type of energy transmitted to the hearing system. For the acoustic hearing aids the energy is transmitted by acoustic waves; for the bone hearing aids the energy is in the form of mechanical vibration transmitted to the bone. For the cochlear implant an electromagnetic signal is distributed by the intra-cochlear electrodes to the cochlea.

In this paper we will focus the attention on the acoustic hearing aids, analyzing the development over the years, the state of the art and prospective of development.

## Hearing Aids

Hearing aid styles have continuously evolved over the past 50 years. From the body-style hearing aids available in the mid-1900s, through the behind-the-ear style hearing aids that became available in the 1960s, and through the smaller and smaller custom instruments that were developed in the 1970s, 1980s and 1990s, an emphasis has been placed on reduction in size and visibility. Today, the smallest hearing aids available are the completely-in-the canal (CIC) style hearing aids, which are worn deep within the ear canal. Besides being very cosmetically appealing, CIC style hearing aids provide significant acoustic benefit because the hearing aid delivers sound to a point very near the tympanic membrane (ear drum). This results in excellent high frequency amplification (good amplification of the high-pitched sounds that are difficult for most individuals with hearing loss to hear). A deep fit in the ear canal leads to a reduction of the occlusion effect. The occlusion effect is caused by an increase in low frequency amplification and leads to the "head in a barrel sound" that you hear when your ear canal is plugged[2].

## Hearing Aid Components

Every hearing aid is equipped with four basic circuitry components, which include a microphone, an amplifier, a receiver, and a battery. The hearing aid microphone picks up sound waves, or acoustic energy, in the air. The microphone converts these sound waves from acoustic energy to electrical energy. The electrical signal enters the amplifier which increases the intensity of the signal in proportion to the needs of the listener. The hearing aid receiver then converts the electrical signal back into acoustic energy perceived by the tympanic membrane, and then processed by the ear. The battery of a hearing aid supplies power to the hearing aid and can vary in size depending upon the style of hearing aid. In general, the larger the battery, the longer it will last[3].

## Hearing Aid Styles

Even though all hearing aids are equipped with the same basic components, they come in different styles. The four most common styles are behind-the-ear, in-the-ear, in-the-canal, and completely-in-the-canal. Behind-the-ear (BTE) hearing aids, as the name suggests, are worn behind the ear and are connected to a hollow plastic hook which is connected to the plastic mold, custom made to fit in the individual's ear. The receiver, microphone and amplifier are all built into the same case (see Figure 1 A).

Batteries on behind-the-ear style hearing aids are relatively large which allows for longer wear between battery replacements[4]. BTEs can be used by patients with a mild to profound hearing loss, and are ideal for individuals with a high frequency hearing loss. About 31% of all hearing aid users wear BTE style hearing aids[5]. In-the-ear (ITE) hearing aids are worn entirely in the concha and external auditory canal. The amplifier, microphone and receiver are all housed in a plastic case that is custom shaped using an impression of the user's ear (see Figure 1 B).

This style of hearing aid can typically be used by patients with mild to moderately-severe hearing losses. This style hearing aid is still able to utilize relatively large batteries. Approximately 38% of hearing aid wearers use ITEs, making this style the most popular. In-the-canal (ITC) hearing aids fit entirely into the external auditory canal with a small protrusion into the concha (see Figure 1 C). Like the ITE, the circuitry is built into a custom-molded plastic case of the ITC. However, in contrast, the ITC occupies the ear canal and only a part of the concha. About 19% of hearing aid users wear ITC style hearing aids. Completely-in-the-canal (CIC) hearing aids are the smallest style of hearing aid. CIC aids are so small that they are barely noticeable in ears because they are inserted deep in the external auditory canal. The amplifier, microphone and re-

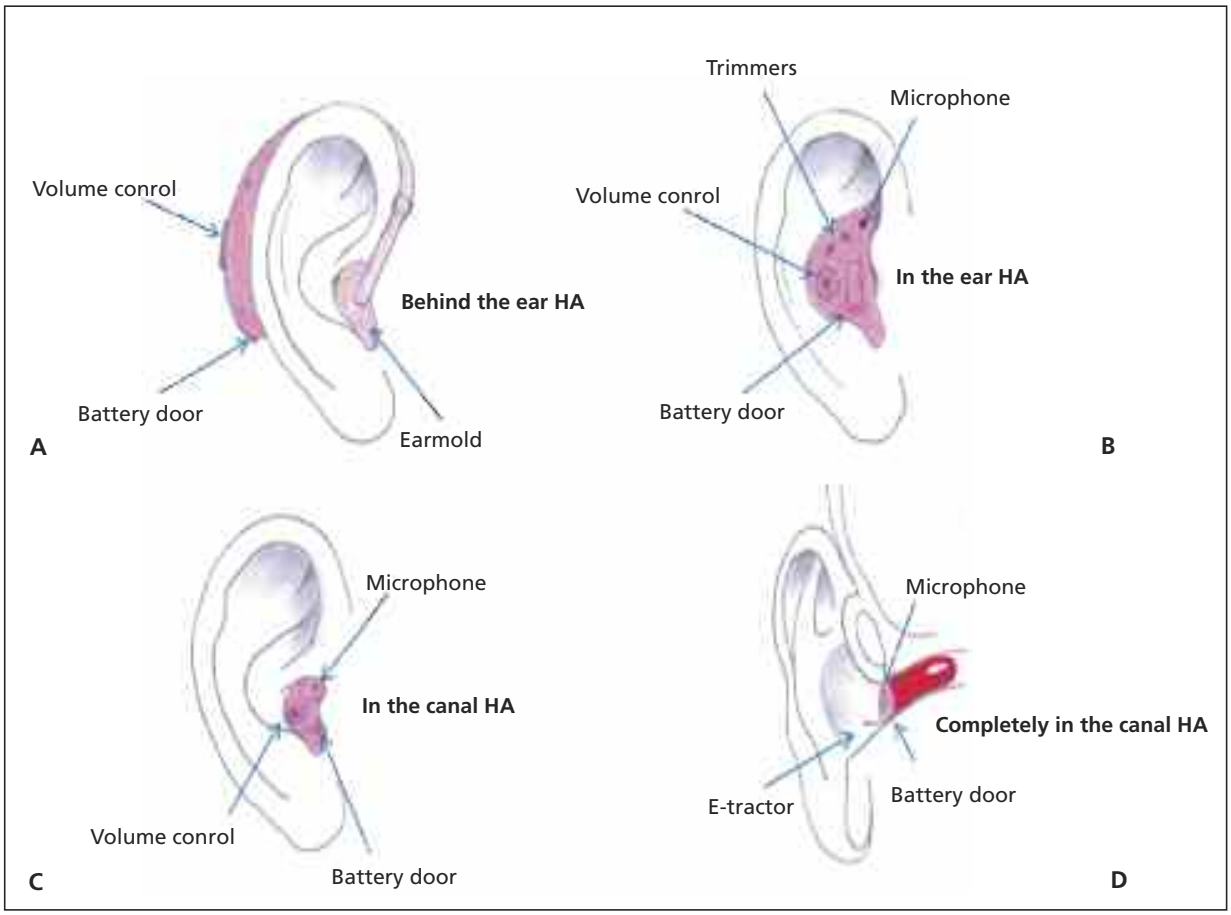


***Figure 1.*** Hearing aid styles. ***A,*** Behind-the-ear (BTE) hearing aids: the receiver, microphone and amplifier are all built into the same case. ***B,*** In-the-ear (ITE) hearing aids: the amplifier, microphone and receiver are all housed in a plastic case that is custom shaped using an impression of the user's ear. ***C,*** In-the-canal (ITC) hearing aids: they fit entirely into the external auditory canal with a small protrusion into the concha. ***D,*** Completely-in-the-canal (CIC) hearing aids: the amplifier, microphone and receiver are all housed in the case of this instrument which is also custom fit in the listener's ear.

ceiver are all housed in the case of this instrument which is also custom fit in the listener's ear (see Figure 1 D). This style of hearing aid can be used for hearing losses that range from mild to moderate and are particularly well-suited to high frequency hearing losses. Because CICs are the smallest style of hearing aid, they require the smallest batteries, which must be changed often. Approximately 12% of hearing aid wearers use CIC style hearing aids.

Each hearing aid style comes with its advantages and disadvantages and clinicians work with their patients to choose the most appropriate style. There are multiple parameters to examine when determining the best fit for the patient. These include where the circuitry of the hearing aid is located on the device, comfort, cosmetic appeal, and battery size.

BTE hearing aids are able to achieve greater gain and maximum output because the microphone is separated from the receiver. Because the receiver and microphone are separated, feedback is less of an issue for behind-the-ear aids. This style of hearing aid is useful in background noise and can be worn by individuals with a mild to profound hearing loss. However, the size of the BTE aids makes this style cosmetically unappealing to some wearers[6].

In-the-ear hearing aids can be worn by individuals with most hearing losses. Full shell ITE aids are the largest of the in-the-ear styles and the half shell is the smaller version of the ITE aids. Although ITE aids are more cosmetically appealing to some over the BTE style, they are prone to feedback problems as the size of the hearing aid decreases because of the closer proximity of the

microphone and receiver. Feedback can be reduced by creating an ear piece that is tightly sealed and by positioning the microphone as far from the receiver as possible. In-the-canal hearing aids require smaller batteries and are not appropriate for all hearing losses because of the limit to their power. ITC aids are cosmetically appealing to some because of their discreetness, but they are prone to mechanical problems due to the amount of moisture and cerumen they are exposed to. This instrument is also prone to feedback issues, again due to the proximity of the microphone and receiver.

Completely-in-the-canal hearing aids are very cosmetically appealing because of their small size and discreetness. CIC style hearing aids provide increases in the usable gain and provide significant acoustic benefits because the hearing aid delivers the sound closer to the tympanic membrane, maximizing high frequency amplification. The outer part of the ear, or pinna, provides amplification for the ear and because this style of hearing aid does not obstruct the pinna it allows for the natural acoustic benefits of the ear canal and concha to occur. The result is an increased amplification of high frequency sounds. Another advantage of the deep fit is a reduction of the occlusion effect[7,8]. Because CICs fit deeply in the ear canal, there is a decrease in bone-conducted signals and vibrations that create "hollow" quality to speech[9]. There are also disadvantages to the CIC style hearing aid. The CIC cannot by worn by all hearing-impaired individuals because it cannot fit into the size and shape of their external auditory canals. Because of the size of the CIC style hearing aids directional microphones cannot be incorporated. The benefits of directional microphones include improved signal-in-noise ratios. Like the ITC style of hearing aids, CICs exhibit mechanical problems because they are worn completely within the warm, moist environment of the ear canal and are constantly exposed to cerumen[2].

Recently, Open Fit hearing aids have been introduced into the market. Open fit hearing aids are similar in style to BTE (behind the ear) aids: a shell sites above the ear and a thin tube travels down from there into the ear canal, but that's where the similarities end. Open Fit BTEs are much newer technology than traditional BTEs, the case above the ear is much smaller and the whole aid is lighter. The *"open"* in the name comes from the fact that aid's earpiece does not fit tightly into the ear canal (Figure 2), as is the case with traditional BTEs, CIC, ITC and ITE models. The earpiece of an open fit hearing aid is a small, soft rubber cap, which is much more comfortable than the tightly fitting earpieces of BTEs, CICs, etc.

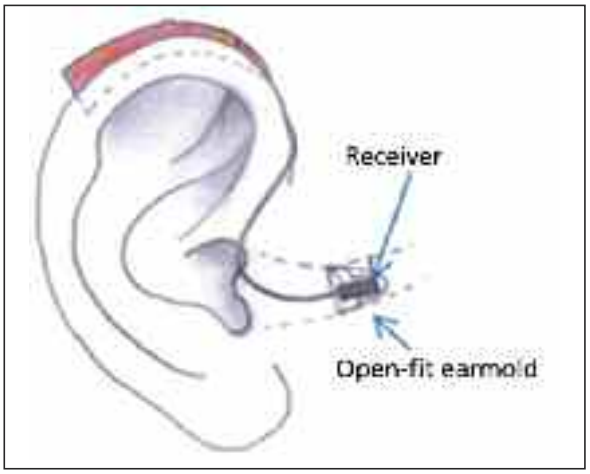


**Figure 2.** Open fitting hearing aids.

There are two types of open ear hearing aids: acoustic thin tube open fit and speaker-in the ear (SIE) hearing aids. The acoustic thin tube hearing aid incorporates all of the electronic components in the plastic case behind the ear. The sound then travels down the acoustic thin tube into the ear canal. The SIE hearing aid moves the speaker from the plastic case down into the earpiece, thus requiring less gain at the ear level to produce the same output in the canal.

Acoustic thin tube open fit hearing aids are not appropriate for many people with a more severe hearing loss, but are ideal for those who have normal low frequency hearing and who are experiencing problems with high frequencies, which usually occurs with early hearing loss[10].

SIE hearing aids are appropriate for both a sloping high frequency hearing loss as well as a wide range hearing loss. Also, because the sound does not have to travel down a thin tube, the quality of the signal is improved so they become available to people with more severe hearing loss.

Open Fit Hearing Aids. Pros and Cons:

- This type of hearing aid does not require an earmold, so it leaves the ear canal unoccluded, providing a more natural sound quality to the user's own voice. For those who have a high frequency loss, the unoccluded ear will hear

low frequency sounds naturally, through the ear canal, offering a more natural sound quality than a hearing aid that fills the ear canal[11].

- The open fitting earpiece helps to reduce the occlusion effect (when the ear is blocked by a hearing aid, the vibrations cannot escape, and are instead bounced back down to the eardrum, which produces the louder hollow sound), but can be more suspectable to feedback (feedback occurs when sound coming out of the speaker travels back into the microphone and is amplified again). The open fit hearing aid uses a FBC (feedback cancellation circuit). It continually monitors the output of the hearing aid to determine whether some portion of the amplified signal contains elements that have the acoustic characteristics of acoustic feedback. When it does, the feedback circuit first determines the frequency, amplitude, and phase of the feedback component and then generates signals of opposite phase that will cancel (or markedly reduce) the feedback component. Since acoustic feedback is often a complex signal (like a tone with a series of harmonics), the cancellation process requires a complex solution, since more than one frequency is involved.
- The fitting time for open fit hearing aids will be shorter than other models because the audiologist/aid vendor will not have to take impressions of the ear to create the moulds.
- Another benefit of the open fit hearing aid is that it is much easier to insert into the ear than a custom hearing aid, because the speaker-in-the-ear hearing aid is one-third the size of a custom fitting.
- Although they utilize the latest technology, open ear hearing aids should not cost much more than standard hearing aids and may even cost the same.
- Because of their size, open fit hearing aids use smaller batteries and will have a shorter battery life than other devices.
- Usually Open fit hearing aids don't give the possibility of manual volume control, because of their size.

The fitting range of a speaker-in-the-ear hearing aid can be a maximum of 60 dB in the low frequencies and 80dB in the high frequencies, including a wide range hearing loss. Patents with more severe hearing loss that require this greater gain can still take advantage of a speaker-in-the-ear hearing aid with the addition of a dome tip ear plug, or custom earmold, which other open fit hearing aids may not allow[12]. While other users may not require an earmold with this type of hearing aid, the addition of one can help to meet the increased gain requirement of those with severe hearing loss with less risk of feedback.

Because the SIE hearing aid is split into two parts, it is easier to repair if breakdowns should occur. The speaker can quickly and easily be replaced in a clinician's office instead of being sent to the manufacturer for repairs[13].

### Hearing Aid Technologies

Technological advances in hearing aids and HATS (Hearing Assistive Technologies, and Rehabilitation Services) have expanded the range of options available to improve the success of a device use. Today's hearing aids differ significantly from their analog predecessors because the application of digital signal processing has permitted many adaptive and/or automatic features. In the past decade, hearing instrument technology has developed to the point that digital hearing aids now constitute nearly 90% of all hearing aid sales in the U.S.[14]. This growth has permitted decreases in the cost of digital technology so that digital hearing aids now span the range from entry-level prices to high-end pricing, thus allowing all users the option of digital technology.

Included in the benefits of digital hearing aids are improved sound quality; multiple listening programs for different listening environments; advanced noise reduction strategies; acoustic feedback reduction; compatibility with remote control options; and flexibility in manipulation of the frequency, compression, and gain[15]. These developments allow the audiologist considerable flexibility in choosing appropriate technology for the varied needs of older adults. Such features as automatic function of the telecoil (a hearing aid component for use with the telephone or for coupling to HATS) and multiple programs ensure that even those with limited manual dexterity or cognitive impairments can wear a device that optimizes performance across a broad range of listening environments. It is no longer necessary to find the switch or remember to return to a listening program when the conversation has ended for effective telephone use.

Difficulty understanding speech in noise is a common complaint for hearing aid users. Directional microphone technology has advanced to optimize the directional responsiveness of the

hearing aid microphone in order to reduce the level of noise when the noise source is from an angle that is behind or beside the hearing aid user. Automatic directional systems are intended to accurately switch between directional and omnidirectional modes, and this option is available even in the lower-priced entry-level digital devices[3].

Technological advances have resulted in miniaturization of many hearing aid and HAT components. These advances have lead to the production of some smaller devices such as mini behind-the-ear hearing aids, completely-in-the-canal hearing aids, and miniature FM receivers. Small devices may not meet the needs of all device users particularly because they may be difficult for an older person to manipulate or adjust. Discussion with the audiologist will ensure selection of appropriate devices to meet each individual's needs. Remote control capability for hearing aids is another available feature that must be carefully considered.

The broad range of devices available, coupled with the flexibility of these devices, has led to increased success in matching technology to the individual needs of those experiencing hearing loss. However, this complexity requires appropriate assessment, selection, and verification, and follow-up to optimize the performance of each user with the chosen device. In modern hearing aid fitting, the audiologist will input data to the software program that provide individual ear acoustics to ensure appropriate output limiting characteristics to provide comfort and protect the residual hearing of the individual. When fitting FM assistive listening systems, it is important that the electroacoustic characteristics of the hearing aid are matched to those of the hearing aid in combination with the FM receiver.

### Future Directions

The hearing aids continue to be developed to enhance the characteristics in terms of rehabilitation and acceptability. One important task is to extend the bandwidth to 8kHz, and make sound more natural. The DSP capabilities have to be developed, like the compression system that automatically reduces background noise levels and ensures speech at an audible and intelligible level. They should be able to better suppress background noise, enhance speech intelligibility, improve sound quality and reduce the occlusion effect. It's obvious that hearing aid technology and wireless technology will converge quickly.

## Conclusion

The use of acoustic hearing aids to compensate some types of hearing loss is an effective solution for rehabilitation, but a specific effort should be devoted to customization and follow-up procedures in order to guarantee the best effectiveness and long-term acceptability. Hearing loss is highly prevalent in the older adult population. Of those persons who would benefit from the use of hearing aids, only a small number actually own and use them.

The styles of hearing aids have drastically changed over the past 50 years. The new technology that is on the market may allow hearing-impaired individuals who can not use CIC instruments (because of degree of hearing loss, irregularly shaped ear canals, or frustration with frequent repairs) to wear discreet instruments that provide acoustic benefits that are comparable to that of current CIC technology.

Technological advances in hearing aids and HATS have expanded the range of options available to improve the success of device use. Older adults today are more technologically savvy than in previous generations, and may be more receptive to the use of technology when it is matched to their specific needs. It is also important that older adults set goals for rehabilitation in partnership with the audiologist. Appropriate and comprehensive assessment, selection, verification, and follow-up by the audiologist are critical. Primary care physicians can assist older adults with hearing loss by ensuring they have access to the services of an audiologist.

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