How to select the optimum BTE fitting option

Abstract

A growing challenge for hearing care professionals is the increasing number of choices and decisions to face when determining how to address the amplification portion of auditory rehabilitation. In particular, for open canal behind-the-ear (BTE) fittings, there are many new choices available. This paper, therefore, will focus primarily on choices involving BTE hearing instruments, with a special emphasis on open canal fittings. We will review many of the traditional reasons for using BTEs and further examine the different technologies and fitting options (i.e. earhooks, tubing and means of coupling to the ear canal). Regarding open canal fittings, the major aspects are understanding maximum insertion gain, occlusion effects and maximum stable gain. It is important to understand how these three factors inter-relate in obtaining the optimum fitting for an individual patient. Prepared with this information, one can incorporate a structured approach to the open canal BTE selection and address individual needs to maximize patient satisfaction.

Background information on open fitting selection:
LifeTip, DoubleDome, custom ear mold ...
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**Rationales for fitting BTE instruments**

Since the time that BTE products were introduced, there has always been a wide assortment of variables to consider in selection and fitting. The recent implementation of new technologies opens wider fitting options. With the variety of hearing losses and lifestyles to be addressed, BTE instruments offer a variety of sizes, technology levels, features and cosmetic options. Many of the potential benefits of the BTE styles are summarized below.

**Power:** BTE instruments have commonly been the preferred choice for more severe to profound hearing losses. The larger housing provides more space for stronger receivers and the necessary suspension support for those receivers.

**Feedback stability:** The distance between the microphone and earmold tip is greater for BTEs than for custom products, which provides the opportunity for increased amounts of power with limited feedback. Increasing the separation of the two also increases the maximum stable gain.

**Features:** A variety of features and feature combinations can be designed for BTEs or for different BTE models in a particular product family that often are not available with custom products due to space limitations. These features often include (in many combinations) directional microphones, volume controls, program buttons, (automatic) telecoils and direct audio input.

**Earmold acoustics:** In many cases, to obtain a desired fitting from both an acoustic and comfort standpoint, it is necessary to alter venting or change the fit of the hearing aid (earmold) in the ear canal. This is much easier to accomplish with a BTE fitting, when the changes can be made to the earmold rather than to the hearing aid itself, as is the case with custom instruments. Venting can have significant effects on low frequency gain, as illustrated in the curves shown in Figure 1.

**Occlusion effects:** A successful approach to relieving occlusion issues is to increase the venting of a hearing instrument fitting. This can be accomplished more effectively with BTEs, as the likelihood of feedback is reduced and the housing is not placed inside the ear canal. With the introduction of digital feedback cancellation systems, a new generation of open ear canal fittings has found rapid success with high cosmetic acceptance and little or no occlusion.

**Cosmetics:** Regardless of whether a BTE looks large or small when placed in one’s hand, when it is positioned behind the ear it usually is very well concealed. New choices for tube diameters combined with tips or small earmolds for coupling to the ear canal can enhance the cosmetic appeal. Also, with the variety of BTE colors available, the BTE fitting can become nearly invisible from any angle in some cases.

**Pediatrics:** BTEs are the preferred hearing aid style for pediatric hearing instrument fittings. With demands for telecoils, FM devices, battery door locks and other features for ease-of-use, the housing of a BTE offers functionality for the child and the parent or caregiver and allows for a more stable fitting on the ear. Additionally, the earmolds can be easily replaced as children grow.

**Wide range of BTE fitting options**

There are many factors to consider in selecting the appropriate BTE. The BTE selected is a combination of technology and coupling that suits the amplification and lifestyle needs of the hearing instrument wearer. Prioritizing these needs simplifies the selection process. Additionally, understanding these needs is what drives manufacturers to increase the availability of solutions for hearing instrument wearers.

A recent and successful change in the BTE product line has been the open canal fittings. The literature has identified many factors which have contributed to the success of this option (e.g., Mueller, 2006; Mueller and Ricketts 2006, Gnewikow and Moss 2006). Typically, with open canal BTEs, the housing is smaller, the tubing is thinner, and rather than using a standard custom earmold, a small, non-occluding tip is inserted into the ear canal. The Siemens family of hearing instruments offers three options for this type of fitting: Life BTEs, Active BTEs and mini BTEs. Siemens mini BTEs refers to the “S-Model” of a hearing instrument family (e.g. CENTRA S, ARTIS S). As shown in Table 1, all three options offer fitting solutions for the most open fittings as well as more occluded fittings for situations when more
LifeTip closed: The closed LifeTip increases the stable insertion gain of the hearing instrument. Thus, more gain can be obtained without feedback. Additionally, the more occluded approach helps prevent some low frequency gain from escaping from the ear canal while still providing minimal occlusion effect. In most cases, the increased low frequency gain increases the observed benefit of adaptive signal processing, such as directional microphone technology and digital noise reduction.

DoubleTip: The DoubleTip provides an extra level of closure to further increase the fitting range with a Life instrument. As the name implies, the DoubleTip has two levels of contact with the ear canal to create a tighter seal. In particular, this tip may be effective for patients with an unusual ear canal configuration, where the single flanged tip may not provide the desired seal.

LifeTube with custom earmold: A fourth coupling option for Life BTEs is using a custom earmold. Most earmold manufacturers create custom earmolds to attach to the LifeTube. The custom earmold can be configured with a variety of vent sizes ranging from a very open CROS-style mold to an occluding mold with no vent. The cosmetics of the Life BTE and the LifeTube are still maintained.

Custom earmold with standard tubing: A final coupling option uses a standard earhook connected to a custom earmold with standard tubing. With Life BTEs, the Life Tubes can be easily unscrewed and a standard earhook attached at any time in the office via a screw-on connection. This choice is ideal for cases where hearing loss has begun to decrease and enables the hearing aid wearer to still take advantage of the output and cosmetics of the Life BTE.

**Active BTE**

CENTRA Active is a variation of the BTE open fitting. CENTRA Active uses receiver-in-canal (RIC) technology with a micro BTE design. Traditionally, receivers are housed in the hearing instrument casing. With a RIC design, an external receiver is positioned inside the ear canal. A thin wire runs from the receiver to the amplifier. The amplifier is housed in a small BTE case to provide added cosmetic benefit. Space-consuming features such as volume controls and push buttons have been omitted. However, multi-memory and volume change options can be controlled via the ePocket™ remote control. As with the Life instruments, CENTRA Active has a relatively generous fitting range. CENTRA Active also offers other wearer benefits including rechargeability and water resistance. These features are offered without compromising battery size, daily use or housing design.

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**Table 1 Overview of BTE fitting options**

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<thead>
<tr>
<th></th>
<th>Active</th>
<th>Life</th>
<th>S-Model</th>
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<tbody>
<tr>
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<td>✓</td>
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</tr>
<tr>
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<tr>
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<td></td>
</tr>
<tr>
<td>Power receiver</td>
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</table>

**Fig. 2** LifeTip, LifeTip closed and DoubleTip (from left to right)

**LifeTube:** The LifeTube is a clear, thin-walled, durable tube with a very narrow diameter. The discrete design of the LifeTube makes it a very cosmetically appealing option. A variety of different LifeTips (see Figure 2) as well as custom earmolds can be attached to the LifeTube.

**LifeTip:** The LifeTip is a silicone tip that attaches to the LifeTube. A variety of diameter sizes provide the opportunity to fit a diverse selection of patients. The LifeTip is designed to provide an open fit with virtually no occlusion effect. The LifeTip is ideal for cases where the hearing in the low frequencies is normal or when a mild low frequency hearing loss exists. The Life tip works very well with ski-slope type hearing losses. As expected, the openness of the fitting allows a great deal of low frequency gain to leak out of the ear canal, and therefore, a more closed style of LifeTip can be used when low frequency gain is desired.

**Siemens Life BTEs**

Siemens Life BTEs offer a very small BTE housing (approximately 1” long) using a 312 size battery. Life BTEs are available in a variety of technology levels. They are an ideal solution for patients with mild to moderate hearing loss seeking an open fit BTE in a discrete package. To address cosmetic requirements, features such as VC and push button are not included on the housing but can be accessed via a remote control option in select models (ePocket). Additionally, as most candidates for Life BTEs perform well on the telephone without a telecoil, this feature is not included.

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3 Wide range BTE of fitting options
Active Dome: The Active dome fits snugly over the end of the receiver and secures the receiver in the ear canal. The C-Guard™ wax protection system protects the receiver from moisture and cerumen in the ear canal (Branda and Chalupper 2007). The open dome provides an open ear canal fitting, very similar to the LifeTip.

Active Dome closed: The closed Active dome helps prevent low frequency gain from escaping the ear canal while increasing the maximum stable gain. There is still little occlusion effect, however.

Active DoubleDome: The double seal helps to maximize the output of the receiver and obtain a tighter seal than is sometimes possible with the standard closed dome, especially for unusual ear canal shapes.

Active custom earmold: This option combines all the benefits of CENTRA Active with the individualized fitting of a custom earmold.

Receiver units: Two different receivers are available to maximize the fitting range of the Active. The standard 45 dB receiver (S-Receiver) is ideal for mild to moderate hearing loss. The optional 55 dB receiver (P-Receiver) is optimal for more severe hearing losses. Both receivers can be easily exchanged by the professional at any time.

S-Model BTE

Siemens S-Model BTEs have consistently provided flexibility by offering an assortment of technology levels and features in a mini-BTE housing. Traditionally coupled to the ear with a standard tube and earmold, the S-Model BTEs are now available with open canal fitting options.

S-LifeTube: The S-LifeTube is a clear, thin tube modeled after the LifeTube. The S-LifeTube easily can replace the earhook and standard tubing to provide both open and cosmetically discrete hearing instrument fittings. This change can be made in the professional’s office using the simple screw-on connection without having to return the instrument to the manufacturer for service.

S-LifeTube with LifeTip: Open LifeTips in a variety of sizes can easily be attached to the S-LifeTube for an open fitting.

S-LifeTube with LifeTip closed: The closed LifeTip maintains the open fitting with increased maximum stable gain and increased low frequency amplification.

S-LifeTube with DoubleTip: The double sealed LifeTip provides maximum stable gain with a non-customized fitting tip.

S-LifeTube with custom earmold: This combination provides the cosmetics of the thin tubing with the comfort and security associated with a custom earmold.

Custom earmold with standard tube: A final coupling option with the S-Model BTE is using a standard earhook and standard earmold with custom tubing. This is optimal when more gain and output is required because the patient’s hearing loss exceeds that appropriate for open fitting.

Selecting the optimum BTE fitting

With the variety of coupling options for the open canal BTE fittings, finding the optimum solution for each hearing aid wearer becomes a matter of identifying goals and needs and matching them to the available features and technology. The following reviews a selection strategy that can be employed.

Selecting a technology

In general, selecting the preferred technology is the first step in the selection process. In the Siemens BTE family, there are several levels of technology ranging from highly sophisticated instruments to those designed with less complicated processing. Choosing the appropriate level of technology generally is based on the patient lifestyle, listening needs and preferences. This information might include time spent in communicating in background noise, previous hearing instrument experience, professional environments and many other factors specific to the wearer.

A principle aspect of selecting the technology is determining the amount of flexibility and additional algorithms built into the hearing instrument. These features can include multichannel frequency shaping and compression, digital noise reduction, speech enhancement, classification systems and many other complex algorithms. All Siemens open fit BTE models in the premium segment are available with the highest levels of adaptive signal processing, e2e wireless, remote control and directional microphones.

An important consideration with determining the technology is to select the appropriate features. Different levels of technology allow various features to be incorporated into the design. The majority of these features are dictated by the hearing instrument circuit. Often, to accommodate discrete housings, features may not be included in some models of the same technology family. For example, as most candidates for open fittings have good hearing in the low frequencies, models such as Life and Active are designed without space-occupying telecoils. However, the CENTRA S BTEs do provide telecoil technology and can accommodate open fittings with the S-LifeTube. Additionally, features such as volume controls
and program buttons may be omitted from smaller housings but are available on the slightly larger S-Models or via the ePocket remote control.

Another important factor to consider is the size of the battery, which somewhat dictates the size of the BTE case. Life hearing instruments often are selected because they use the smaller 312 sized battery. If a patient desires the convenience of rechargeable batteries with hearing instruments, as with the CENTRA Active, the small size 10 and 312 batteries do not provide sufficient capacity for a full day of operation. A size 13 rechargeable battery still allows a small housing along with the practical convenience of rechargeability.

A convenient tool providing a quick overview of available hearing instruments equipped with special features like telecoil, directional microphones and VC is the “Hearing instruments” tab in CONNEXX.

Selecting a coupling: comparative measures

One of the factors that contributes to the success of open canal fittings is the limited impact on the resonance of the ear canal when it is occluded with the tip, dome or earmold. One method of demonstrating the “openness” of the fitting is to conduct a measure referred to as the Real Ear Occluded Gain (REOG). To conduct this test, the signal is presented to the occluded ear and measured via a probe in the ear canal with the hearing instrument turned off. The difference between the input signal and the measured signal is the REOG. Figures 3 and 4 show REOG measures for the LifeTip and Active Dome in open, closed and double sealed conditions.

Observe that the open dome shows little impact on the resonance effects of the ear canal. As the ear canal becomes more occluded, there is more impact, especially in the higher frequencies. The low frequencies in both the open and closed conditions show little effect below 1000 Hz and the DoubleDome shows only a moderate impact on the low frequencies. For most patients, the double sealing will have a greater impact for Active Domes than for LifeTips.

As mentioned, the reduction of the occlusion effect is popularly associated with open fittings. The REOG with the DoubleTip and DoubleDome (Figures 3 and 4) indicate that the low frequencies are more impacted by the additional seal, which would suggest a possible increase in occlusion; however, the signal source with the REOG is an external signal. A true occlusion effect is a reaction to a self-generated signal. Figure 5 indicates occlusion measures for 10 subjects, 5 male and 5 female, with the DoubleTip and the DoubleDome. Results are compared to those obtained from different studies following the same protocol using vocalizing “ee” to create an “internal” test signal (Mackenzie et al. 2007). The results indicate that for 500 Hz and 1000 Hz, one may see a 4 to 6 dB increase in occlusion, consistent with the corresponding REOG responses. The lower 250 Hz region is less impacted. The perception of the occlusion effect is very individual. For many patients, occlusion related to the DoubleTip or DoubleDome may not be noticeable.
The occlusion effect can be measured objectively; however, the degree of annoyance caused by this effect is subjective and can vary between individuals. It can be expected that when occlusion issues are present, selecting a more open fitting is likely to resolve or reduce those issues. A practical approach for addressing open fitting is to begin with the most open option. More occluding options can then be used as needed.

The maximum insertion gain from the instrument is influenced by the tightness and depth of the coupling in the ear canal. Hence, the ear canal coupling directly impacts the fitting range of the hearing instrument. For example, the more occluded the ear canal, the less likely it is for low frequency gain to escape, and consequently, the fitting range in the low frequencies is greater. Figures 6 and 7 provide measurements showing the leakage of low frequencies with the various open tip options. As discussed and demonstrated in the figures, one can expect more useable gain in the low frequencies with a more occluded fitting. The resulting fitting ranges (assuming NAL-NL1 as target and allowing for some headroom) are shown in Appendix II.

Insertion gain can also be increased by increasing the physical gain and output of the hearing instrument. As discussed, traditional BTE models are designed with the receiver secured inside the housing. With the Active BTEs, the RIC design offers an added advantage for creating the preferred fitting for the individual patient. The replaceable receiver unit provides the opportunity for more than one receiver size and power level. For more mild to moderate losses, a 45 dB receiver can be used. When addressing more severe losses, the 55 dB receiver can be used to provide more gain and output. Note, however, that the power receiver is somewhat larger and therefore may lead to more occlusion in small ear canals.

The output of a BTE instrument can also be influenced by the tubing. With RIC instruments, this is not a factor as there is no tubing conducting sound from the instrument housing to the ear canal. However, with the Life instruments and the S-Model BTEs, it is important to note that the smaller LifeTube and S-LifeTubes will reduce the high frequency gain. In regard to open fittings, there often is a concern with feedback. Current feedback cancellation systems have increased the amount of stable gain that can be achieved by approximately 10-20 dB, compared to the previous generations of hearing instru-
Selection procedure

In summary, a successful open BTE fitting can be achieved by following a simple series of steps and taking into account the different factors that can influence an open BTE fitting. A simple selection procedure is shown in Figure 10. Note that this procedure is valid for hearing losses of primarily sensorineural origin with a PTA < 80 dB HL and assumes that OPEN is used for open fittings (LifeTip open, Dome open, S-LifeTip open) and NAL-NL1 acclimatization level 2 for more occluding fittings (closed Dome and LifeTip, S-LifeTip, custom earmolds). For conductive hearing losses, typically, considerably more gain is required. The procedure consists of four steps:

- Selection of model
- Selection of tube or receiver size
- Selection of coupling to ear canal
- Optimization of coupling to ear canal

Most important is discussing the goals and priorities of the hearing instrument wearer. With this information and the audiologic requirements identified, the first step is to select the technology which provides the appropriate functionality for the patient’s lifestyle and hearing loss. With the model (Life, Active or S-Model) selected, the next step is to choose the appropriate tube or receiver size by taking into account the hearing loss at high frequencies. Finally, the best coupling option (open, closed, double sealed, custom earmold) is determined by the hearing loss at low frequencies.
If feedback should occur, then simply choose the next more occluding tip to eliminate the feedback. If this causes an occlusion issue, it may be necessary to consider a more open fitting option. Due to individual ear canal anatomy, shape of hearing loss and susceptibility to occlusion, this procedure may not work for every individual patient, but should provide a good starting point or general guideline for most patients.

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<th>HL@2 kHz &gt; 70 dB?</th>
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<td>&gt;55 dB</td>
<td>Standard tube</td>
</tr>
<tr>
<td>50-55 dB</td>
<td>Life tube</td>
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<tr>
<td>40-50 dB</td>
<td>45 dB receiver</td>
</tr>
<tr>
<td>&lt;40 dB</td>
<td>55 dB receiver</td>
</tr>
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</table>

**Fig. 10** Procedure to select individual BTE fitting option based on technological and audiological requirements.
Appendix I: Case studies

Case study #1

Ben Wilson is a recently retired gentleman who has worn hearing instruments for the past five years. He and his wife spend a considerable amount of time sailing. They often entertain friends on their boat and enjoy the flexibility to travel as they please. Communication is often challenging in group situations or when the wind is blowing. Another challenge for Ben is dealing with the exposure of his hearing instruments to water while sailing.

His audiogram shows a mild sloping to severe sensorineural hearing loss, bilaterally. He has previously worn digital CIC hearing instruments in both ears. The sound of his own voice has often been an issue. We have suggested a binaural fitting with CENTRA Active.

CENTRA Active is an appropriate choice for Mr. Wilson and his lifestyle. The AquaProtect™ features (clip-on microphone cover, nanocoating and C-Guard) will help shield his hearing instruments from exposure to the elements while he is outdoors sailing. The sophisticated classification system of CENTRA technology allows him to be very active in a variety of situations without requiring him to change programs. The hearing instrument can analyze the environment and select appropriate settings for the various environments. With the automatic and adaptive multichannel directional microphone technology, Mr. Wilson can expect good performance in noisy situations such as when he and his wife are entertaining guests on their boat.

Additionally, when CENTRA Active detects wind, it will transition to the omnidirectional microphone mode and reduce the low frequency gain. The clip-on cover will provide additional protection from wind noise. With these processing features, CENTRA Active will adjust to changes in the listening environment without Mr. Wilson needing to stop his current activity. Also, should he find more specified demands from his listening environments, Mr. Wilson can always add a remote control for multiple programs.

With the rechargeable batteries, Mr. Wilson can leave his hearing instruments in the charger overnight to assure a full day’s performance the next morning. Additionally, the charging unit uses a drying agent to absorb any moisture from the hearing instruments. If he is traveling and is unable to recharge his batteries, Mr. Wilson always has the option of using a standard zinc air battery.

Due to the degree of his hearing loss, a 10 mm closed dome was used to help prevent feedback issues without compromising amplification. Additionally, with the reduced leakage of low frequency amplification, there will be less negative impact on directionality.
Appendix I: Case studies

Case study #2

Susan Toth is an elementary school principal. She has never worn hearing aids but has noticed difficulties understanding her husband as well as students at school. She is a fan of classical music and enjoys going to concert halls with friends or watching television at home. She also indicated that professionally, she interacts with a variety of students, parents and faculty. This often is in her quiet office, but it is not uncommon to be in a noisy area. With the variety of situations she is in and with the challenge of both louder students and softer-speaking students, she felt strongly that she would like to have control over the instruments in those situations.

She expressed an interest in using direct audio input for watching television. She has had some exposure to this technology from interactions with students with hearing loss at her school and has an interest in using this with television at home. In addition, as many churches and concert halls are equipped with induction loops, she would like to have a telecoil.

Her audiogram indicates normal hearing in the low frequencies dropping to a moderate sensorineural hearing loss in the high frequencies.

We have suggested using a CENTRA S and CENTRA S VC with the S-LifeTube and open LifeTip along with the ePocket remote control. Looking strictly at the audiogram, Mrs. Toth appears to be a perfect candidate for a Life or Active hearing instrument. However, her interest in direct audio input suggests that she may prefer an S-Model BTE. Using the S-LifeTube allows us to make this an open fitting as well as meeting her audio input request. Additionally, e2e wireless provides use of the ePocket remote control for the various situations she encounters. Choosing the CENTRA S and CENTRA S VC models gives her the functionality of the volume control and program button on the instruments in case she does not have her ePocket easily accessible. The directional microphones offer better performance in noise. The addition of an infrared system for her home theater system will allow her to utilize the audio input for listening to television.

“The optimum selection of the best fitting option is a valuable tool in maximizing benefit and achieving patient satisfaction.”
Appendix II: Fitting ranges

Fig. 13  Fitting ranges for CENTRA Life

Fig. 14  Fitting ranges for CENTRA Active (45 dB receiver)

Fig. 15  Fitting ranges for CENTRA Active (55 dB receiver)

Fig. 16  Fitting ranges for CENTRA S
Conclusions

Addressing the individual needs of the hearing instrument wearer is a priority in any hearing instrument fitting. Satisfying cosmetic concerns and maintaining comfort and audibility for different listening environments must be accomplished to ensure the wearer uses the amplification provided. Factors such as the occlusion effect and maximum stable gain, which are very individual to each patient, need to be addressed with little compromise. Open fit BTEs, with their variety of technology and coupling options, enable hearing care professionals to fulfill all individual needs. The optimum selection of the best fitting option is a valuable tool in maximizing benefit and achieving patient satisfaction.

References

Siemens Audiologische Technik (2007).
CENTRA Active – A new receiver-in-canal solution designed to enhance patient satisfaction.

Siemens Audiologische Technik (2007).
A Rechargeable Battery System for Hearing Instruments.

Siemens Audiologische Technik (2007).
AquaProtect: Three Innovative Features to Protect against Moisture.

A New System to Protect Hearing Aids from Cerumen and Moisture.

Hearing instruments.

Hearing aid outcomes with open and closed canal fittings.

Open-canal fittings and the hearing aid occlusion effect.

Open is in.

Open-canal fittings: Ten take-home tips.