A FORGOTTEN TECHNIQUE FOR RESOLVING THE OCCLUSION EFFECT

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It is not uncommon for patients fit with an occluding earmold or custom shell hearing aid to complain that their own voices sound hollow, boomy or as if they are "speaking in a barrel." When listening to others talking, the voices sound OK and do not have this annoying characteristic. The patient is likely experiencing the well-known occlusion effect.

Soft, instant-fit eartips coupled with thin-tube or receiver-in-canal (RIC) hearing aids have made fitting most high-frequency hearing losses simple. Difficult-to-fit losses can be resolved in moments and the occlusion effect usually is not a problem.

As a result, some of the techniques and procedures used in past years to deal with the occlusion effect are less emphasized today. Yet there are a substantial number of cases where knowing and using modification techniques can be extremely useful, especially when fitting custom products and aids using standard tube (#13) earmolds. This article is intended to reacquaint us with these traditional and effective procedures.

How does the occlusion effect sensation arise and what is its cause?

When a patient is fit with an occluding earmold/shell and has pure tone thresholds better than 30dB (or even in some instances, 35–40dB) in the low frequencies, between 125 Hz and about 1,000 Hz, they will usually become aware of this annoying low-frequency sensation when talking (Dillon, 2001; Killion, Wilber, & Gudmundsen, 1988; Kuk, Keenan, & Lau, 2005; Kuk, Peters, Keenan, & Lau, 2005). The hearing loss may have any audiometric configuration (e.g., high-frequency, gently or abruptly sloping, flat, or rising). The patient may be a man or a woman (Mueller, Bright, & Northern, 1996), but personal experience suggests that men with deep voices may experience these negative effects more often. Moreover, patients may not adapt to or become accustomed to the occlusion effect percept; it will not simply disappear over time (Kiessling et al., 2005).

When an individual produces a voiced sound, the vibrations within the vocal tract (larynx, nasopharyngeal column, etc.) are transmitted by bone conduction through the skull to the ear canal (Bekesy, 1960; Goldstein & Hayes, 1965; Khanna, Tonndorf, & Queller, 1976; Tonndorf, 1972). When talking, the movement of the articulators (i.e., the mandibular condyle) causes minute displacements of the cartilaginous portions of the ear canal (Dillon, 2001; Franke, Gierke, Grossman & Wittern, 1952; Zemlin, 1998). Together, these sources of vibration set into motion air particles within the ear canal across the frequency spectrum. These self-generated acoustic effects are always present when a person vocalizes or talks, regardless of whether the ear canal is open or occluded. In the case of the open canal, this transmission of a patient's own voice is not perceived negatively because the sound is leaked into the environment outside the ear. However, when the ear canal is occluded with an earmold/shell that terminates in the cartilaginous portion, the sound is unable to escape and is trapped. The occluded ear canal becomes a resonant cavity, and the low frequencies, which have been boosted, pass into the cochlea because the impedance at the tympanic membrane has become favorable to the passage of the low-frequency portion of the spectrum (Tonndorf, 1972).

The inside story

This discussion assumes that:

1. A hearing aid functions to amplify only the natural, environmental sounds that come from outside the listener, across the frequency spectrum, lows to highs.

2. When the aid involves an occluding earmold/shell, another source of low-frequency sounds arises from inside the listener's ear canal, and these sounds are reinforced and enhanced independently of the amplification provided by the hearing aid.

This acoustic effect of self-generated low-frequency sound is why applying a low cut to the hearing aid's frequency response to eliminate the occlusion complaint will ordinarily not make the "speaking in a barrel" sensation disappear; the occlusion effect is not a function of the amplification provided by the hearing aid (Kuk et al., 2005; Mueller, 2003). It is the simple presence of an occluding earmold or shell that gives rise to the unnatural, hollow sensation when talking, and this is the circumstance that must be dealt with. Some publications discuss the effect of a similarly annoying sensation of amplification called ampclusion, (Kuk & Ludvigsen, 2002; Painton, 1993; Sweetow & Pirzanski, 2003) on the assumption that the patient may be experiencing a negative perception due to amplification that is not based solely on the occlusion effect (Kuk et al., 2005). It is suggested that both factors may be present at the same time. For our purposes, and in agreement with others (Kuk et al., 2005) we've concluded that most of the hollow voice complaints are earmold/shell related, and specifically dealing with them is by far the most important issue.

You can determine for yourself if the patient is experiencing the true occlusion effect as opposed to a new, unfamiliar or degraded sound of amplification. With the aid in place, turn it off and ask the patient to speak or phonate a vowel, such as [ee] or [o]. (In bilateral fittings, remove the contralateral aid.) If the occluded sensation is still present, gently break the seal of the aid, or pull it slightly out of the ear. If the sensation disappears or lessens as the aid is loosened, you've identified the culprit.

Investigators have attempted to quantify the frequencies and the magnitude of the SPLs at which the occlusion effect occurs in the canal (Goldstein & Hayes, 1965; Kampe & Wynne, 1996; Killion et al., 1988; Revit, 1992). Occlusion effect SPLs vary in amplitude between patients from as little as 5–9dB to 25–32dB, with peaks at different frequencies (Fulton & Martin, 2006; Killion et al., 1988; Mueller et al., 1996). Instrumentation and techniques are available for measurement of the occlusion effect in the office, but we might ask ourselves whether the time spent performing measurements is worthwhile. The reality as Dillon (2001) suggests, is that it is the patient who will have to tell us whether his/her individual occlusion effect continues to be disturbing or not as we try to resolve it. Examining a set of objective measurements cannot tell us this, although it may be valuable for record keeping.

What Can Be Done About It?

The utilization of vents of appreciable size is the most common and most popular recommendation for dealing with the occlusion effect (Grover & Martin, 1979; Kiessling et al., 2005; Kuk et al., 2005; MacKenzie, Browning, & McClymont, 1989; Tecca, 1991, 1992). Large vents shunt a portion of low-frequency signals to the environment, removing all or part of the disturbing low-frequency own-voice elements. Kuk et al. (2005) showed a linear relationship between the acoustic mass of vents and the objective, measured level of SPLs in the ear canal. They found that as the vent diameters were increased, the SPLs in the occluded canal decreased in an orderly, predictable manner. Although modeled data are discussed, these investigators did not measure the effect of shortening the vents. Shortening vent length while

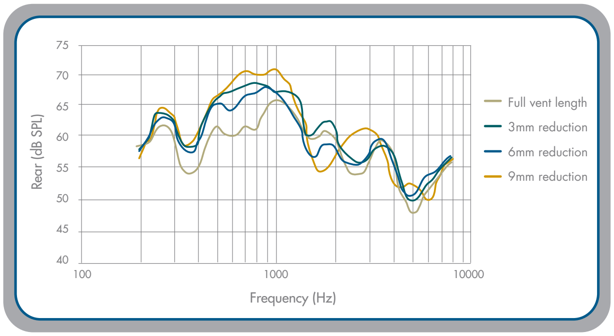

Figure 1: Shortening the vent from the tip results in a reduction of SPL in the ear canal. The probe tube depth was held constant during voicing of /i/ as the vent was shortened approximately 9 mm from the tip in a custom in-the-ear (ITE) hearing aid.

holding the diameter constant also results in a reduction of acoustic mass; therefore, vent shortening will also reduce the occlusion effect (Dillon, 2001). Figure 1 is an example of the reduction in gain afforded by shortening a two-millimeter vent in one patient. Note a reduction of approximately 20dB in the low frequencies.

Ordinarily, one can expect slit leak (the escape of sound around the circumference of the mold/shell) to also increase as the vent is shortened. Each time slit leak increases, a little more of the low frequencies are leaked (Macrae & McAlister, 1989; Studebaker, Cox, & Wark, 1978). The end result of a shortened vent is the reduction of acoustic mass combined with slit leak that together produce a substantive decrease in low-frequency SPLs.

It would be nice to be able to choose a priori the exact vent diameter and length that would resolve the occlusion effect in a given patient, but vent dimensions have not been found to be systematically related to the perceived amount of occlusion effect (Kampe & Wynne, 1996; Kiessling et al., 2005; Kuk & Keenan, 2006; Kuk et al., 2005). For this reason, it's impossible to predict the level of perceived occlusion effect reduction that a patient may experience with a given vent diameter/length. We do know that a very small, long vent will invariably elicit a judgment of a significant occlusion effect (Dillon, 2001; Fulton & Martin, 2006; Kiessling et al., 2005), while shortened vents and those with diameters of three millimeters or larger serve very well to significantly reduce or eliminate the occlusion effect in patients (Dillon 2001; Kuk & Keenan, 2006; Kuk et al., 2005).

The Solution: Shortening the Vent

Contemporary hearing care professionals more familiar with open-fit standard products using non-custom tips may question the value of learning or utilizing the practical bench skills that are required for earmold/shell modification. What follows is an example of how useful and powerful a simple modification can be in dealing with this frustrating fitting issue. Shortening the vent is possibly the easiest and safest technique, although others have been suggested (Chung, 2004; Curran, 1991; Sweetow & Pirzanski, 2003). This modification is effective for all types of custom aids and for earmolds fabricated from acrylic or made of any material with reduced flexibility. It provides a reliable means to achieve step-by-step, orderly, incremental reduction of the occlusion effect (Curran, 1990). The basic tool to use is a motor tool, with appropriate burrs. Smoothing and polishing is done by means of a larger buffing wheel.

The proper way to shorten the vent is to start from the tip of the earmold/shell, the part that terminates in the ear canal, and remove by grinding away, in small steps, a little at a time, the material that surrounds the vent (see Figure 2). The approach is the same no matter what size the vent is. The path of the vent is followed as it becomes exposed, and small amounts of material are

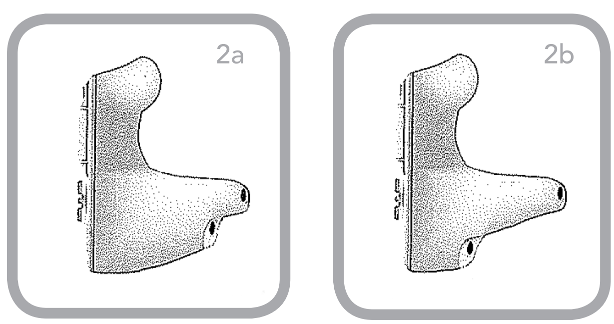

Figure 2a: An example of a vent that has been shortened by grinding approximately 6.4 mm from the tip.
Figure 2b: An example of a vent that has been shortened by grinding approximately 16 mm from the tip.

removed by the grinding. A kind of "trench" may be formed by the sides of the vent; the sides should be removed and flattened. All surfaces are smoothed and buffed to eliminate roughness each time before reinserting the aid to determine if the occlusion effect has been sufficiently reduced. It may require a few "cut and try" repetitions before a final resolution is reached. It goes without saying, of course, only the vent itself is shortened; the sound bore or receiver tube is left alone.

When the vent has been shortened substantially, you might opt to enlarge the diameter of the remaining shortened vent by also drilling from the outside exterior surface (or faceplate side) toward the inside. A slightly larger drill (burr) can be used to increase the vent diameter. In effect, you will have proceeded from an essentially closed, occluding mold/shell to a more open "IROS" configuration. Starkey Hearing Technologies' effective adaptive feedback cancellation algorithm reduces much of the concern about feedback as you "open" the earmold/shell.

You'll know when you've shortened or opened the vent enough when patients report the hollowness in their voices has disappeared when they talk. Patients immediately recognize the difference. To review: we established earlier that a change in the acoustic mass of a vent will cause a change in the SPL in the ear canal (Dillon, 2001). The shorter a vent is, the less acoustic mass it contains when compared to a longer vent. We also expect that as the SPL inside the canal is reduced, the patient's perception of the "hollow" sensation will also subside. Add to this the effect of slit leak (which also produces escape of low-frequency SPLs), and with this simple maneuver you've caused the patient's distressing perception of his or her voice to diminish or disappear. You have at your fingertips (literally) a wonderful in-office method for eliminating the occlusion effect complaint.

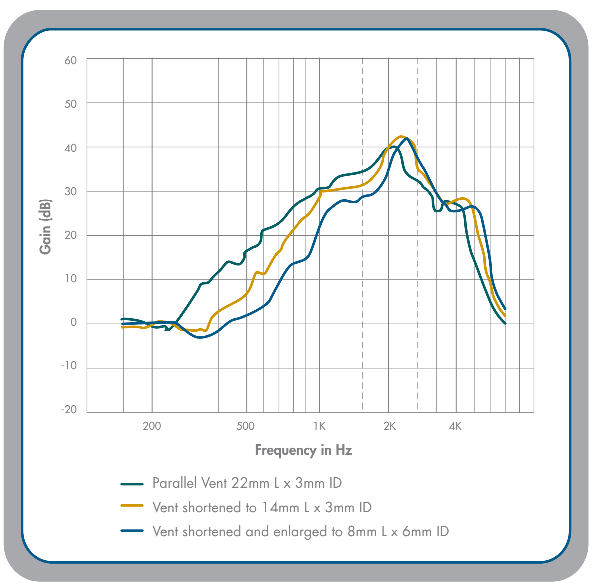

Figure 3: The acoustic effect of shortening and enlarging a parallel vent on a custom ITE instrument. A probe tube was inserted 4 mm beyond the tip of the aid through a second probe vent and glued in place throughout the shortening.

Figure 3 shows the acoustic effect of shortening and enlarging a parallel vent on a custom in-the-ear (ITE) instrument. A probe tube was inserted four millimeters beyond the tip of the aid through a second probe vent. The diameter of the original vent was three millimeters, and its length was 22 millimeters. The vent was shortened to a length of eight millimeters and enlarged to six millimeters. The Real-ear Aided Gain (REAG) curves show a substantive reduction of low-frequency energy without diminution in the higher frequencies.

Planning Ahead

In adults with small ear canals and especially in children, the earmold/shell may accommodate only the smallest of vents. When inspection of the audiogram shows thresholds better than 30–35dB in the low frequencies where the occlusion effect can be expected to occur, earmold/shell configurations with pre-shortened vents can be ordered. Further vent shortening can be implemented at the initial fitting, if needed.

It might be assumed that Select-A-Vents would provide an easy method for reducing the occlusion effect, on the assumption that a simple change of the insert plug to a larger diameter would be all that is needed. Generally, Select-A-Vent inserts will have little effect on reducing the own-voice effect if the vent into which they are installed is long and narrow; only when the vent is short and/or wide will inserting a large-diameter insert plug have a meaningful impact on low-frequency (and occlusion effect) reduction (Dillon, 2001; Valente, Enrietto, & Layton, 2002). However, Select-A-Vents might be useful in maintaining amplification in the higher frequencies where some reduction may occur as the earmold/shell is opened (Dillon, 2001). Here, real-ear measurements coupled with the patient's report about the perceived occlusion effect can be used to establish whether a given Select-A-Vent insert has any value.

Conclusion

There are numerous occasions where a software-driven response adjustment alone is inadequate for resolving the occlusion effect. Patients fitted with custom ITE and completely-in-canal (CIC) products or with behind-the-ear (BTE) instruments having thin tube or #13 tubing earmolds often present the need for occlusion effect reduction. Effective and reliable, this simple, in-office, on-the-spot modification of the coupling apparatus can be counted on to provide immediate relief. The vent shortening technique is recommended for use whenever occlusion effect problems intrude. Over the years, earmold/shell modification has been considered an invaluable fine-tuning adjunct to the modern fitting process.

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