Out of the Barrel: Reducing Occlusion in CICs With Custom Venting

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When a person speaks, the vibrations of the vocal tract are transferred through the skull. This vibration causes intense sound pressure levels to be generated in the ear canal (Dillon, 2001). When wearing an occluding hearing aid the sound cannot escape the ear canal and the wearer's own voice is amplified, causing a potentially negative perception of own voice quality. Kuk, Keenan, and Lau (2005) found that when wearing an occluding earmold, a patient's own voice can be up to 17 dB above prescribed gain in the low frequencies. Not surprisingly, MarkeTrak V (Kochkin, 2000) found that occlusion ranked 4th out of 32 complaints; indicating that occlusion is a very common issue for hearing aid wearers.

There are two effects that drive the negative perception of occlusion; the first effect is caused by physically plugging the ear. The second is caused by a combination of the occluding effects of plugging the ear and the amplification produced by the hearing aid (Sweetow & Pirzanski, 2003). One way to alleviate the combination of these effects is to reduce low frequency gain. This may help alleviate the increased loudness of one's own voice; however, the audiologist may run the risk of under amplifying low frequency sounds. If the problem is due only to the physical occlusion of the ear canal, one accepted option is to create a larger vent in the hearing aid. It has been shown that increasing vent size will decrease this negative perception of occlusion and the associated comments such as degraded own voice quality (Dillon, 2001; Kiessling, Brenner, Jerspersen, Groth, & Jensen, 2005; Kuk, et al., 2005).

Similar in concept to large venting, receiver-in-the-canal and slim tube behind-the-ear (BTE) hearing aids fit in an open configuration have the same or greater effect on occlusion which may be one of the reasons for the rapid gain in popularity in recent years. Data from the Hearing Industry Association showed that BTEs comprised 57% of all sales in 2008 (although this is not broken up into 'open-canal' and traditional fittings) (AudiologyOnline, 2009). This fitting configuration has given patients access to cosmetically appealing hearing aids, appropriate amplification and perhaps most importantly, little to no occlusion. However, there are still a large number of individuals who prefer to wear a custom device rather than a BTE style device. For many, the Completely-In-the-Canal (CIC) style device is more cosmetically appealing and easier to use than the BTE style.

With the recent focus on open-canal fittings, it is possible dispensers have overlooked the increasingly flexible venting options available in custom hearing aids. Traditionally, expectations were that CICs simply could not accommodate large vents. Further, with larger vents came the risk of increased feedback. Today, with the advancements in feedback cancellation and advanced manufacturing techniques, CICs can be built with large vents and short canals while still accommodating a wide fitting range.

A research project was developed to quantify the effects of increasing vent size on acoustic transparency in custom CIC products. Bilateral sets of CICs using five different vent configurations were manufactured for five adult participants, resulting in a total of 50 test devices. The devices were manufactured using Stereolithography (SLA), a process that digitally scans the ear impression, producing identical shells that differ only in the vent configuration. The vent configurations can be seen in Table 1.

1V/2V standard vent 	BAV 
Dual Vent 	I/O Vent 

Table 1. Vent configurations used in current study.

The 1V (1mm) and 2V (2mm) vents are standard sizes, which can be created during the SLA process. The other three vent configurations are sized based on the constraints of the ear space and earmold impression. The BAV, Dual, and IROS Open (I/O) vents are customized by hand to every individual earmold. By customizing each vent, the manufacturing technicians are able to achieve the largest vents possible in every ear. The I/O and dual vent options use all available space remaining on the hearing aid faceplate. All test devices, within a subject, were approximately the same length, showing a good consistency in the custom fabrication of the units.

The real-ear unaided response (REUR) and real-ear occluded response (REOR) were recorded for each vent configuration. The REUR is the measured SPL in the ear canal as a function of frequency in an open ear. The REOR is the SPL in the ear canal as a function of frequency, with the hearing aid placed in the ear and turned off (Mueller, Hawkins, & Northern, 1992). For the purpose of this study the REOR is reported. This measurement will be referred to as *acoustic transparency*—indicating how much sound reaches the ear drum as it passes from outside the ear, past the inactive hearing aid and to the eardrum. A measure of acoustic transparency offers insight toward the occluding effects of the hearing aid. A response that approximates the REUR would be considered an open-canal fitting; a response that shows a reduction in sound level at the eardrum, when compared to the REUR, can be considered an occluded fitting. Each real-ear response was obtained using the Audioscan Verifit Real-Ear system. Real-ear occluded measures were completed with the recommended male voice (carrot passage) presented at 65 dB SPL, at a distance of 18" from the speaker, with the probe tube approximately 4-6mm beyond the tip of the receiver port (end of shell) on the device.

Results of the measurements can be seen in Figure 1. The average response recorded for the REUR shows good agreement with the average REUR reported by Mueller et al. (1992). The average response of the various vent configurations demonstrate a systematic increase in peak acoustic transparency when increasing vent size from the 1v to the Dual and I/O vents. Between the I/O vent and the 1V vent there is a 12.4 dB peak difference in the averaged responses. Additionally, each millimeter increase in the size of the vents corresponds to a 1-2 dB increase in acoustic transparency.

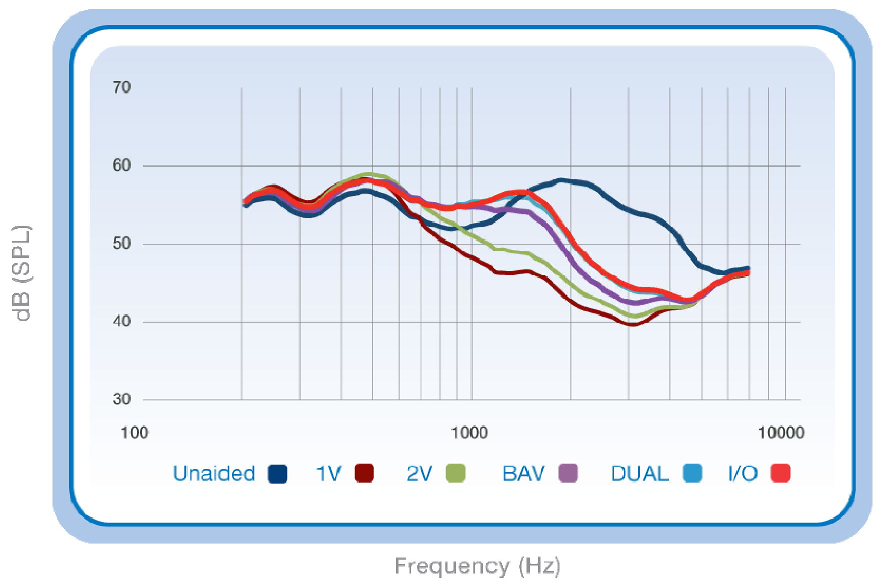

Figure 1. Average REOR measurements with the various venting configurations.

Table 2 lists +/- 1 standard deviation for the measures of acoustic transparencies at select frequencies. The standard deviation varied as a function of frequency however it was consistent across vent sizes.

+/- 1 Standard Deviation						
Vent	500 Hz	1 kHz	2 kHz	3 kHz	4 kHz	6 k
1V	1.38	3.08	4.14	2.22	1.43	1.52
2V	1.45	1.83	4.50	2.83	1.79	1.54
BAV	1.33	2.65	5.28	3.26	2.01	1.49
Dual	0.99	2.24	4.29	3.19	2.40	1.46
I/O	1.09	1.91	4.11	3.72	2.20	1.47

Table 2. +/- 1 standard deviation for the measures of acoustic transparencies at select frequencies.

These data demonstrate that increasing vent size also increases acoustic transparency, which may reduce perceived occlusion (Kiessling et al., 2006; Kuk et al., 2005). Kuk and colleagues (2005) suggest that if vent length stays constant while vent diameter increases the occlusion effect will be decreased. This is in agreement with the findings of the current study; all devices were the same length leaving vent diameter as the mitigating difference. This reinforces the expectation that listeners with the largest available custom vents such as the Dual and I/O may experience the least occlusion.

The flexibility of large venting options like those discussed here has increased greatly in recent years. Developments in repeatable SLA based manufacturing techniques have improved the consistency and comfort of custom hearing aids. Combined with advanced feedback cancellation strategies, a wider range of users can now be fit with these hearing aids. All of these factors combine to increase options for custom hearing aids and provide patients with CIC hearing aids that are more comfortable and less occluding than the hearing aids of the past.

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