How does venting affect an ADRO® fitting?

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Abstract

Venting enhances comfort and quality of sound for hearing aid users who have hearing thresholds below 45 dB HL at 250 and 500 Hz. However, venting also affects the gain and output levels achievable with the hearing aid. The calibration and fitting of ADRO® hearing aids depends on whether the earmold is vented and the size of the vent. At the present time, the ADRO® fitting predictions do not take into account the venting of the earmold, and the recommended calibration procedure is to block the vent during calibration. It may be possible to reduce fitting time in the future by taking venting into account, but if the procedures and advice below are followed, fitting an ADRO® hearing aid with a vented earmold is not difficult. To avoid acoustic feedback, the Maximum Gain parameter for ADRO® fittings needs to be limited to lower values for a vented hearing aid than for an unvented aid. Recommended values are tabulated below, and Dynamic Hearing has developed an automatic feedback manager to help find appropriate Maximum Gain values using an in-situ measurement of the gain at which feedback oscillations first occur.

Background

The primary goals of the ADRO® amplification strategy are to improve the audibility of soft sounds and the comfort of loud sounds heard through a hearing aid [1, 2, 3]. The first goal requires the hearing aid to operate with an amplification gain that is high enough for soft sounds to reach the threshold of hearing of the listener. For the ADRO® strategy, the hearing aid gain is constrained to lie below the Maximum Gain parameter that can be specified by the audiologist at the time of fitting at each audiological frequency shown in the fitting software.

The useful range of Maximum Gain settings will be limited by the occurrence of feedback oscillations which occur when the hearing aid gain becomes larger than the attenuation between the hearing aid output transducer and the hearing aid microphone. Under these conditions, the output of the hearing aid will become unstable and the hearing aid will oscillate or whistle. Conventionally, feedback oscillation is avoided by using a tight-fitting earmold with no vent to ensure that sound does not leak from the hearing aid output to the microphone.

The comfort of the listener using a hearing aid is not only affected by the output level of loud sounds, but by physical characteristics such as the fit of the earmold and the quality of the sound. When the ear canal is completely or partially blocked by the earmold, the listener's own voice sounds louder at low frequencies because of the "occlusion effect" which causes sound conducted to the ear via the bones of the head to be amplified relative to the level that it would have if the ear canal was completely open. The amount of amplification can be up to 20 dB at some frequencies if the ear canal is completely blocked by the earmold. To reduce the size of the occlusion effect, and to increase physical comfort of the listener, a vent of varying diameter can be inserted into the earmold or hearing aid shell.

The ADRO® amplification scheme has been used successfully with vents, despite the conflicting requirements between the need for high Maximum Gain to improve audibility, and the need for a vent to increase physical comfort and minimize the occlusion effect. The contents of this paper provide useful information designed to allow the audiologist to reach a good compromise between these requirements.

Calibration of vented hearing aids

ADRO® hearing aids are calibrated so that the audiologist can specify the output levels of the hearing aid in a 2cc coupler, and the Maximum Gain of the hearing aid in a 2cc coupler. For a behind-the-ear (BTE) hearing aid, the calibration measurement is done by connecting the hearing aid output to the coupler with a length of tube. There is thus no vent in the system for the measurement. Similarly, when an in-the-ear or in-the-canal aid is calibrated, the vent should be blocked to produce results that are consistent with those for BTE aids.

Dynamic Hearing's ADROfit software displays output and gain parameters relative to the 2cc coupler calibrations. Our reason for choosing this type of calibration was so that we would have a consistent reference that was measurable in a hearing aid test box without the need for the hearing aid client to be present.

The predictions for Maximum Output Level, Comfort Target, Audibility Target, and Maximum Gain parameters for ADRO are all based on clinical and research experience using the 2cc coupler calibration method. If a different calibration method was used (for example with the vent open), the predictions would need to be changed accordingly. If a real ear response calibration method was used, venting would be one of several factors affecting the calibration.

The real ear response

If the audiologist or the manufacturer wishes to calculate output levels or gains for the hearing aid in the listener's ear, various correction factors need to be used. These include the Real Ear to Coupler Difference (RECD) for output levels, coupler response for flat insertion gain (CORFIG) to convert from coupler gain to insertion gain, corrections to gain according to the microphone position, and the effect of venting. The CORFIG factors are included in Table 1 as a function of frequency.

Alternatively, the real ear response can be measured directly using a probe-tube microphone. This is the most accurate method, and is often recommended for very young children where behavioural responses cannot be used and a theoretical fitting prescription is used to set the hearing aid parameters.

Table 1. CORFIG factors for different hearing aid styles. Values are in dB.

	BTE	ITE	ITC
500 Hz	-3	-4	-4
1000 Hz	-3	-3	-4
2000 Hz	1	1	-1
3000 Hz	6	1	-2
4000 Hz	6	-5	-8
6000 Hz	-4	-13	-13

Selecting vent size

To obtain the best possible comfort and performance for an ADRO® hearing aid, it is recommended that the vent size should be as small as possible while avoiding physical discomfort and large occlusion effects. The following paragraph is quoted from Dillon [4] page 149.

"Based on the patient's hearing thresholds at 250 and 500 Hz, estimate the minimum vent size needed to overcome the occlusion effect. Good research data on this are not available, but as a guide, low-frequency losses greater than 45 dB do not need a vent, and low-frequency losses less than 30 dB must have at least a 2 mm vent …"

Note that recommended vent sizes tend to be larger for listeners with milder hearing losses. Vents are not recommended for clients who need high gain.

Measuring Comfort Levels with a vent

It is not recommended that Comfort Levels are verified below 750 Hz for listeners using a vented hearing aid. There are two main reasons for this. Firstly, the effect of the vent is to allow sound to escape from the ear canal, especially at low frequencies. This means that the output transducer of the hearing aid would have to be driven very hard to achieve a comfortable level at low frequencies in the vented aid. The second reason is that low frequency parameters often need to be adjusted later in the fitting process to optimize the sound of the listener's own voice. For more details, see the section on Voice Optimization below.

Setting Maximum Gain with a vent

The Maximum Gain parameter of an ADRO® fitting is designed to control the loudness of very soft sounds. Higher Maximum Gain means lower aided thresholds and better response to soft sounds. However, high Maximum Gains and venting together may lead to feedback oscillations, especially at high frequencies. Tables 2, 3, and 4 show the highest gain settings recommended for different hearing aid types and vent sizes to avoid feedback. The values were adapted from Tables 5.2, 5.3, and 5.4 in Dillon's book on hearing aids [4].

Table 2. Maximum coupler gain (in dB) before feedback oscillation for BTE hearing aids with hard acrylic earmolds having various vent sizes. The most likely frequencies for feedback oscillation are 3 and 6 kHz.

	No vent	1 mm	2mm	3.5 mm
500 Hz	62	62	57	48
1000 Hz	61	58	54	49
2000 Hz	57	53	50	44
3000 Hz	47	45	42	37
4000 Hz	51	51	47	41
6000 Hz	46	43	44	37

Table 3. Maximum coupler gain (in dB) before feedback oscillation for ITE hearing aids having various vent sizes. The most likely frequencies for feedback oscillation are 4 and 6 kHz.

	No vent	1.5 mm	2mm
500 Hz	50	53	46
1000 Hz	46	50	43
2000 Hz	34	38	34
3000 Hz	25	27	25
4000 Hz	17	20	18
6000 Hz	0	2	0

When feedback occurs, it is worthwhile to compare the Maximum Gain for the fitting with the highest gain shown in the appropriate table. If the actual Maximum Gain in the fitting is lower than the highest gain in the table, it may be possible to improve the fit of the earmold and achieve the desired Maximum Gain. However, if the actual Maximum Gain in the fitting is higher than the highest gain in the table, it is likely that the earmold is already well fitted and it is impractical to use the desired Maximum Gain setting.

The use of soft earmold materials and tight-fitting earmolds may allow the use of Maximum Gain values higher than those shown in the tables.

Table 4. Maximum coupler gain (in dB) before feedback oscillation for ITC hearing aids having various vent sizes. The most likely frequencies for feedback oscillation are 3 to 6 kHz.

	No vent	1.5 mm	2mm
500 Hz	44	43	37
1000 Hz	41	41	34
2000 Hz	36	33	31
3000 Hz	21	26	19
4000 Hz	20	23	19
6000 Hz	-2	-1	4

Active feedback suppression

Dynamic Hearing has developed active feedback suppression (AFS) technology to reduce the effects of feedback oscillation if it occurs. AFS will temporarily reduce the Maximum Gain of the ADRO® hearing aid if feedback oscillations are detected. This reduction in Maximum Gain will reduce whistling, without affecting the perception of music or other sounds at moderate input levels when the hearing aid is not usually operating at maximum gain. Although AFS will help if feedback occurs occasionally, it is not a substitute for appropriate choice of vent sizes and Maximum Gain parameters to avoid feedback oscillations in the first place.

Using the feedback manager

Dynamic Hearing has used the same feedback oscillation detection technology that is used in the active feedback system to produce an automatic feedback manager. The feedback manager will optimize the Maximum Gain settings for the individual, while the hearing aid is in the listener's ear.

The feedback manager can operate in two modes. In the Maximum Gain reduction mode, the feedback manager will monitor the sounds produced by the hearing aid and reduce the Maximum Gain at frequencies where feedback oscillation occurs. The Maximum Gain reduction mode is designed to be used after a fitting has been done, but there is still persistent feedback oscillation. Use of the feedback manager may reduce the high-frequency Maximum Gain settings below the listener's preferred values to avoid feedback. Low and mid frequency gains will usually not be reduced if the vent size and earmold fit are appropriate for the listener.

The second mode of operation of the feedback manager is the gain increase mode. This mode is designed to be used before a fitting has been created, and will result in a set of highest Maximum Gain settings that could be used for the individual's hearing aid, earmold and vent configuration. These values are more accurate than the values shown in Tables 2, 3, and 4 above.

If the audiologist subsequently sets the Maximum Gain parameters higher than the values returned by the feedback manager in either gain increase or gain decrease mode, it is likely that the listener will experience persistent feedback oscillations, and the active feedback suppression (AFS) system will operate continually if it is turned on. This is not a desirable solution to the problem, and the preferred solution is to reduce the Maximum Gain to prevent feedback oscillations from occurring persistently.

Voice optimization

For a person with a mild hearing loss and a vent in their hearing aid, there may be a complex interaction between three different sound conduction paths. Bone conduction conveys low frequency sound to the ear canal, and the level in the canal can be magnified by up to 20 dB if the canal is occluded by the hearing aid or earmold. The second path is air conduction through the vent. This is the usual path by which people hear their own voice when they are not using a hearing aid. The third path is via the hearing aid itself. The time delays along the three paths can be different, with bone conduction having a very short conduction time, followed by direct air conduction, and with the hearing aid adding further delay due to the processing of the signal inside the hearing aid.

Often, the easiest way to avoid uncontrolled interaction between the different components is to allow one to dominate the other two. For a person with a moderate or severe hearing loss, the dominant component will usually be the amplified sound. For a person with a mild hearing loss and a vented hearing aid, the direct air conduction path may be the dominant sound. For a mild hearing loss, voice quality can be helped by using a vent, and reducing the Maximum Gain of the hearing aid at low frequencies. For moderate and severe hearing loss, voice quality can sometimes be improved by increasing Maximum Gain at low to mid frequencies.

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