Adding Precision to the Initial Hearing Aid Fitting

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Introduction

We have heard about the research indicating that happy customers tell eight friends about their positive experiences with a service or product while unhappy, dissatisfied customers tell their tale to 16 people (Deming, 1982). A patient’s initial experience has a huge impact on his overall acceptance and satisfaction of our services. Achieving an accurate and custom initial fitting will have a huge impact on initial satisfaction and the overall success of a professional practice.

There are two hearing aid functions designed to create a level of precision in setting and matching gain targets. These are in situ audiometry and integrated real-ear measures. In general, in situ audiometry corrects the hearing threshold levels (HTLs) for the insertion effects of the hearing aid. This correction allows the target gains to represent the hearing loss more accurately. The real-ear measures enable the hearing aid to match those target gains with more precision. The result is a fitting that is based on the actual characteristics of your patient rather than average data.

In Situ Audiometry

In many cases, the hearing aid fitting software has a built-in audiometer to obtain hearing levels with the hearing aid in the ear. This procedure is called in situ audiometry. “In situ” is a Latin phrase meaning “in place” and is used in many different contexts, often indicating that measurements or observations are made without disturbing the original environment. In the case of hearing instruments, it refers to measurements taken with the hearing aid in its natural location: correctly fitted in the ear.

When we measure hearing levels in situ we have the opportunity to observe how standardized audiometric hearing levels will vary because of the influence of residual ear canal volume. The procedure also accounts for the effects of the depth of the instrument in the ear canal, the effectiveness of the seal in the ear canal, the effects of venting, and the specific receiver in that instrument.

A demonstration of how the hearing aid insertion depth will affect the real-ear gain is shown in Figure 1. In this chart, zero represents the average real-ear insertion response (REIR) and the curves represent the mathematical variation one could expect if the depth of the hearing instrument insertion were increased and decreased one and two standard deviations. The data suggest that deviations from normal can be more than 10dB. Gain targets calculated without considering a 10dB increase in REIR will overestimate the amount of gain needed and result in a fitting that requires extensive adjustments to achieve acceptable listening levels (DeJonge, 1996).

When we are using the fitting software to set the target and perform the initial adjustments we rely exclusively on the hearing levels obtained during the audiologic evaluation. The fitting formulas used to set the target gain contain the proper algorithms to compute the gain targets based on the desired input levels and hearing instrument style. However, these algorithms are all based on average data. By including data obtained for your specific patient and his or her specific hearing instrument, we are adding a level of customization that your patients expect from the sophisticated digital technology used today. The in situ audiometer may also allow the direct measurement of in situ loudness levels (LDL) measures using the same tools you use to

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measure in situ hearing levels. The importance of having the correct LDL in the fitting of the hearing aid cannot be overstated. According to Mueller and Bentler (2008) many patients are still not being fitted with the proper maximum output. They recommend pre-fitting frequency-specific LDL measures and post-fitting loudness verification.

In situ audiometry allows you to customize the targets for your specific patient and, by doing so, improve the accuracy of the fitting. As a result, all the other processes operate with the same customized accuracy. Once the channel gain is set for all input levels, the feedback cancellation algorithm computes a cancellation filter precisely for the hearing aid you have fit to your patient. The general compression parameters are set up to provide the proper gain adjustment for soft, comfortable, and loud inputs based on your patient’s auditory thresholds corrected for the insertion effects of the hearing instrument.

By customizing the fitting process for your patient’s hearing instrument, you will save valuable patient contact time. The initial fitting will be based on your patient’s requirements rather than average data and will result in much more acceptable baseline settings. In turn, this will reduce the time needed for troubleshooting complaints such as those associated with high-frequency gain, occlusion, or tolerance issues. The result is more time for patient counseling and training and improved initial patient satisfaction.

To evaluate the effect of insertion depth in a real-world environment we measured the differences between insertearphone and in situ thresholds for CIC and ITC fittings (Ioannou, 2000). The results are shown in Figure 2. Thirty ears were fitted with CICs and ten ears were fitted with ITCs. Prior to the fittings, HTLs were measured using ER-3A insert ear phones. After the hearing aids were fit, the HTLs were retested using in situ measures.

Typically, CIC fittings result in a deeper insertion compared to ITC fittings. The results showed the expected trend. CICs produce smaller residual cavities compared to ITCs and thus the differences between conventional HTL and CIC in situ HTL were greater than the same comparisons for ITC fittings. We also found that the differences increased with test frequency. In general, however, using the conventional HTL overestimated the size of the residual cavity and would have resulted in a fitting that had more gain than was needed. This relates to findings presented in MarkeTrak VI (Kochkin, 2002). More than 80% of respondents in that survey felt that hearing aids should make loud sounds less painful and should offer improved sound quality compared to the unaided condition. One reason might be that deeper-than-average fittings will produce more amplification than needed on the first fit. Unless it is adjusted during followup, these fittings will result in an initial complaint that loud sounds are too loud.

To further investigate the perceptual effects of insertion depth variations, 18 participants with an average age of 66 (44 to 74 years) were fitted with multi-memory hearing devices. All participants were previous users of well-fit hearing aids based on probe-microphone verification.

For each participant, one memory was best fit using HTLs measured using conventional ER-3A insert earphones. A second memory was best fit using HTLs measured in situ. The participants did not know how each memory was set and the memory settings were counterbalanced among the participants. Each participant was instructed to switch both sides of the binaural fitting to the same memory in each phase of the study.

The participants were asked to rate various listening situations for clarity, loudness, naturalness of the sound, and overall sound quality. Their memory preference was recorded. The results showed that 11 participants, about 61%, preferred the fitting based on the in situ responses. Six preferred the ER-3 based fitting and one had no preference (Ioannou, 2000).

This small-scale, in-house study demonstrates what we found over several years of clinical experience with in situ measurements. The ability to apply tools to customize the response for the specific hearing instrument as it is fit to the patient will provide a more accurate fit and increased patient satisfaction.

Integrated Real-Ear Measures

Once the HTLs are corrected for the hearing aid insertion effects, the hearing aid must be calibrated so that its gain response matches the gain targets. The best method to calibrate the gain response is to measure the relationship between the 2cc coupler measures used in manufacturing...
with the patient’s actual residual cavities. That is, to measure the differences between the sound pressure level (SPL) generated in the patient’s ear to the SPL generated in the 2cc coupler. In this way, the hearing aid gain algorithm knows exactly how much voltage is needed to produce the required gain in each frequency band. This calibration can only be done directly using probe-microphone measures.

Probe-microphone or real-ear measurements as a technique for objectively verifying the performance characteristics of a hearing aid are recommended as a best practice in hearing aid fittings (Valente, 2006). However, it is not widely used for reasons such as expense, time limitations, and the need for cumbersome equipment. As a result, about 60% of hearing professionals do not use real-ear measurements (Kirkwood, 2006).

An efficient method for using real-ear measurements is available in fitting software that integrates a key measure into the fitting process. This method uses the real-ear coupler difference (RECD). The acoustic characteristics of a hearing aid are quantified in a standard 2cc coupler. Such coupler responses are defined in the ANSI standards (ANSI 1996) and are used to describe hearing aid performance. However, coupler responses are not designed to indicate the performance of the hearing aid in an actual ear. We can estimate the real-ear response of a hearing instrument if the coupler response and the difference between the coupler response and the real-ear response are known. That estimation is the RECD. Its derivation is simple: measure the output of a signal in the real-ear, measure the same signal in a coupler, and then subtract the coupler SPL from the real-ear SPL (Figure 3). Once the RECD is measured, adding it to a known coupler response provides a means of predicting the real-ear response from the coupler response.

Hearing aid manufacturers generally use an RECD in their fitting software to calculate a simulated real-ear response, which is then displayed as part of the fitting software. The hearing aid has the stored coupler response of the hearing aid and, by adding an average RECD, that coupler response can predict the real-ear response. An average RECD is used since the actual RECD of the ear under test is not known. The use of average RECD data creates a mismatch between the gain required to match the target and the gain produced by the hearing aid.

RECD varies considerably from one ear to another in the adult population as shown in Figure 4. In this study, the same hearing aid was fit to a number of different ears, without changing any settings, and probe microphone measures were taken (Yanz and Olson, 2006). Differences in the acoustic characteristics of the ear canals are quite apparent and speak to the need for individual measures to add precision to the fitting rather than relying on average data. The target match will be inaccurate for the individual ear to the extent that the average RECD is different for the ear under test. Figure 4 shows a range of variation in excess of 15dB.

It is clear that to create a precise target gain match, the use of average RECDs falls short. To assist the hearing professional with the measurement of the patient’s RECDs we have developed a system that allows the hearing instrument itself to measure the patient’s RECDs and use those data to predict the real-ear aided response. The use of individual RECDs provides not only a precise gain target match but also allows programming changes with the same precision.

Can a simple system built into a hearing aid produce results with the same accuracy and reliability as a standard real-ear system? To examine the accuracy of the Integrated REM system, we compared the predicted real-ear gain obtained with a commercial real-ear system. An example is shown in Figure 5. Initially the predicted real-ear gain based on the average RECD (orange line) is compared to the gain obtained using the measured RECD (green line) for the same patient. We can observe the difference between the predicted gain based on average data compared to data measured in the patient’s ear. We then added the gain measured by standard real-ear equipment (blue line, AudioScan VeriFit) to judge the accuracy of the gain prediction using Integrated REM. In this case, the predicted gain using a commercial real-ear system matches that using the Integrated REM system. In the same study we examined the results of 52 target matches and found that the Integrated REM system matched a standard NAL-R target within ±3dB (Figure 6). The results using the Integrated REM system were as accurate and reliable as those obtained with a standard commercial system (Yanz and Olson, 2006).

Although the RECD allows us to predict real-ear SPL from coupler SPL, the real-ear aided response (REAR) is also affected by the hearing aid style. As the style of the hearing aid becomes smaller, the location of the microphone changes. In general, the microphone is closer to the
entrance to the ear canal as we go from BTE to CIC. These microphone location effects (MLE) are consistent. Data collected in our research facility showing corrections for MLEs as a function of frequency are stored in the Inspire OS software for each model (Figure 7). These corrections are used to add one more degree of precision based on hearing aid style. The coupler response is stored in the hearing aid. The MLE is stored in the fitting software based on the style selected. The RECD is measured from the patient’s ear. Thus, an accurate prediction of an individual’s real-ear aided response is achieved according to the following formula:

\[ \text{REAR} = \text{coupler response} + \text{RECD} + \text{MLE} \]

A graphic representation of how the RECD is used to model the response of the hearing aid is shown in Figure 8. When we use the fitting software to change the hearing aid response, the changes are made to the coupler response. The MLE and measured RECD then correct the coupler response to reflect the specific patient characteristics.

**Conclusion**

We have seen how the basic hearing test data can be customized to reflect the actual patient’s performance with a hearing aid and how those data are used to develop hearing aid gain targets specific for that individual. In addition, we learned how individually-measured RECDs are integrated into the fitting software display models to accurately represent the response in the patient’s ear. These two systems in concert allow us to monitor the actual response of the hearing aid during the initial fitting and as we make fitting adjustments.

It is clear that in order for sophisticated fitting software to develop a precision first fit it must have the most accurate data. Reliance on average data to convert HTLs to target gain predictions and the use of average RECDs to match those targets does not offer the patient the best initial results. The key to a successful fitting is in the patient’s experience on the day of his first hearing aid fitting. Using data obtained directly from your patient will ensure the most accurate initial fitting and will help deliver high patient satisfaction.

**References**


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