Case Report

Challenges in Fitting a Hearing Aid to a Severely Collapsed Ear Canal and Mixed Hearing Loss

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Abstract

Background: Collapsed ear canals typically occur when an outside force, such as a headset for audiometric testing, is present. However, when a collapsed ear canal occurs without external pressure, this creates a challenge not only for performing audiometric testing but also for coupling a hearing aid to the ear canal.

Purpose: This case report highlights the challenges associated with fitting a hearing aid on a patient with a severe anterior-posterior collapsed ear canal with a mixed hearing loss.

Research Design: A 67-yr-old female originally presented to Washington University in St. Louis School of Medicine in 1996 with a long-standing history of bilateral otosclerosis. She had chronic ear infections in the right ear and a severely collapsed ear canal in the left ear and was fit with a bone anchored hearing aid (BAHA®) on the right side in 2003. However, benefit from the BAHA started to decrease due to changes in hearing, and a different hearing solution was needed. It was proposed that a hearing aid be fit to her collapsed left ear canal; however, trying to couple a hearing aid to the collapsed ear canal required unique noncustom earmold solutions.

Conclusions: This case study highlights some of the obstacles and potential solutions for coupling a hearing aid to a severely collapsed ear canal.

Key Words: Bone anchored hearing aid, collapsed ear canal, hearing aid

Abbreviations: BAHA = bone anchored hearing aid; NAL-NL1 = National Acoustic Laboratories' nonlinear fitting procedure, version 1; REAG = real ear aided gain; REIG = real ear insertion gain; REUG = real ear unaided gain; WRS = word recognition score

Fitting hearing aids to any patient can present a number of challenges. These challenges can escalate exponentially when a patient presents with unusual or atypical circumstances in his or her case history. One unusual or atypical challenge is a patient presenting with a severely collapsed ear canal that can make it very difficult, if not impossible, to make an impression of the ear canal or allow an earmold to be retained in the ear canal.

Marshall and Gossman (1982) suggested that a collapsed ear canal is caused by degeneration of elastic fibers and a decrease in collagen causing the tissue within the ear canal to lose its elasticity and strength. Randolph and Schow (1983) report that 35% of patients between 60 and 69 yr of age and 36% of patients between 70 and 79 yr of age will present with a collapsed ear canal. Further, Scrow and Goldbaum (1980) report that 51% of patients 80 yr and older had collapsed ear canals. In most of these cases, the ear canal has a normal appearance until an earphone is placed over the ear. When this happens, the pressure from the earphone collapses the ear canal. In some cases, however, the ear canal can become collapsed without any

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external pressure, creating an even greater challenge in performing a hearing test and particularly in trying to fit a hearing aid.

This case report details the efforts of the authors to try to provide amplification to a severely, naturally collapsed ear canal combined with a mixed hearing loss utilizing various coupling methods.

CASE HISTORY

The patient was a 67-yr-old white female who visited the Division of Adult Audiology at Washington University in St. Louis School of Medicine in 1996. She had previous audiometric evaluations and had been examined by an otolaryngologist at this clinic prior to 1996, but previous medical records were no longer available.

Her available medical records reported she had been diagnosed with bilateral otosclerosis and she had a fenestration/mastoidectomy surgery performed in her right ear in 1949 and a stapedectomy in her left ear in 1974. At her first documented visit in 1996 she reported bilateral hearing loss, tinnitus, otorrhea, and problems understanding speech. She wore a left in-the-ear hearing aid that she had purchased in 1985. Audiometric testing (Fig. 1) revealed a moderate to moderately severe mixed hearing loss from 250 to 4000 Hz, precipitously sloping to a profound hearing loss from 6000 to 8000 Hz in the right ear. Results for the left ear revealed a mild to moderate mixed hearing loss from 250 to 2000 Hz, sloping to a moderately severe to profound mixed hearing loss from 3000 to 8000 Hz. Word recognition scores (WRSs) were obtained using the recorded female version of the Northwestern University Auditory Test Number 6 (NU-6; Tillman and Carhart, 1966) word lists and revealed WRSs of 94 and 92% in the right and left ears, respectively. During this visit the right ear was cleaned due to otorrhea.

Throughout the next few years the patient was examined frequently by an otologist to have the right ear cavity cleaned due to otorrhea and infection. During an appointment in December 1999, it was noted that the left ear canal was narrower, but it is unknown as to why the left ear canal was starting to collapse in an anterior-posterior manner. The patient stopped wearing a hearing aid in her left ear in 2000 as the hearing aid started to produce a large amount of distortion and she did not want to repair it at this time. In 2001, the bone anchored hearing aid (BAHA®) was first mentioned as a possible amplification option due to the chronic external otitis in the right ear and the collapsed ear canal in the left ear. The right side was discussed as the site of implantation due to the slightly better bone conduction thresholds and because a hearing aid could not be worn in this ear due to chronic otorrhea and infections. After some consideration, the patient decided to pursue a BAHA, and in November 2002, the titanium screw and abutment for the BAHA were implanted with no complications. The Compact™ BAHA processor was fit in January of 2003 with a directional microphone connected to the direct audio input (DAI) at the bottom of the processor. Aided sound field testing was performed using the NU-6 word lists presented at a level of 63 dB SPL and at a +6 dB SPL signal-to-noise ratio. Unaided WRSs were 0% for both listening environments and 64% in quiet and 26% in noise when aided with the BAHA. The patient reported significant benefit at the time of the initial BAHA fitting.

In 2005, the patient reported deterioration in performance/benefit with the BAHA that the patient attributed to a decrease in hearing sensitivity and suprathreshold distortion. It is unknown why an audiometric evaluation was not performed at this time; however, an audiometric evaluation in May 2006 revealed a 15 dB decrease in the left ear at 4000, 6000, and 8000 Hz (see Tables 1 and 2 for serial audiograms from 1996 to 2011 for air and bone conduction thresholds, respectively). In addition, there was a decrease in WRSs to 72 and 74% in the right and left ears, respectively, compared to the last obtained WRSs of

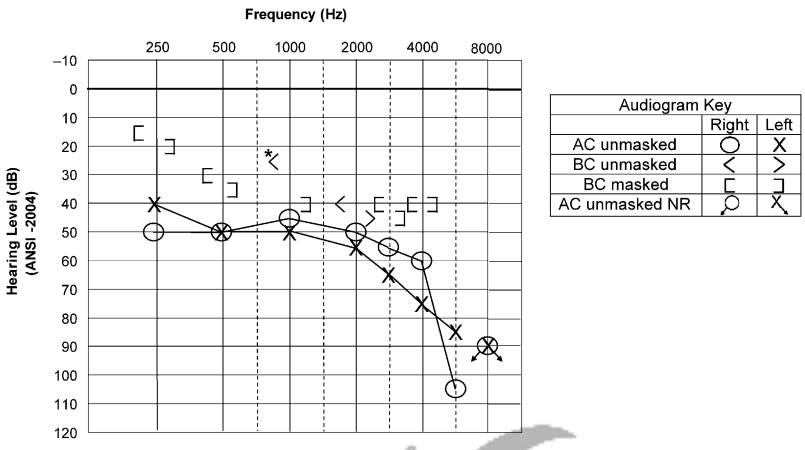

Figure 1. Air and bone conduction thresholds obtained in 1996. *Could not mask due to magnitude of the air conduction threshold in the nontest ear, range of effective masking, and limits of the audiometer; AC = air conduction; BC = bone conduction; NR = no response.

Table 1. Pure-Tone Air Conduction Thresholds (dB HL)

	Right								Left							
	Frequency (Hz)															
Year	250	500	1000	2000	3000	4000	6000	8000	250	500	1000	2000	3000	4000	6000	8000
1996	50	50	45	50	55	60	105	NR	40	50	50	55	65	75	85	NR
1998	55	50	45	40	50	55	110	NR	50	50	50	55	55	60	90	NR
1999	50	50	45	45	50	65	105	100	50	50	45	55	65	65	90	100
2000	50	50	50	55	65	90	105	105	60	55	60	60	70	75	100	NR
2001 (Inserts)	100	90	70	60	70	95	105	NR	80	65	60	55	65	65	75	95
2001 (Headset)	65	55	60	55	65	85	105	110	50	50	55	55	65	65	100	105
2004	60	70	70	70	75	95	105	NR	70	65	60	60	70	70	80	85
2006	60	65	70	70	85	95	NR	NR	65	60	60	60	65	85	95	100
2007	75	60	70	60	75	95	NR	NR	65	55	55	60	70	75	90	95
2009	75	55	70	65	80	100	NR	NR	65	50	55	60	75	85	90	90
2011	60	60	70	65	80	105**	110	NR	55*	55	55	60	75	85	85	95

Note: NR = no response.

*Could not mask due to magnitude of the air-bone gap in the nontest ear.

**Could not mask due to limits of the audiometer.

86 and 96% in 2001 (see Table 3 for history of speech recognition thresholds and WRSs from 1996 to 2011). It is important to note that in 2001, pure-tone air conduction thresholds were obtained utilizing a headset and insert earphones. Results from this testing revealed that the headset had minimal effect on pure-tone air conduction thresholds in the left collapsed ear canal when compared with insert earphones, and therefore, the headset provided an accurate assessment of pure-tone air conduction thresholds. The noted decrease in low frequency thresholds between the headset and insert earphones is due to the use of immittance probe tips as insert earphones in this clinic, rather than the conventional ER-3A insert earphones. Immittance probe tips allowed leakage of low frequencies that, therefore, elevated the severity of hearing loss at these lower frequencies. Throughout the following years the patient continued to report a decrease in benefit with the BAHA and increased difficulty in background noise.

FITTING AMPLIFICATION TO THE SEVERELY COLLAPSED EAR CANAL

The patient recently returned to Washington University in St. Louis School of Medicine Division of Adult Audiology clinic in January of 2011 for an annual audiogram. Her most recent audiogram revealed WRSs of 56 and 54% in the right and left ears, respectively (Fig. 2; Note that bone conduction threshold testing was not performed at this visit due to no significant changes in air conduction thresholds from the previous audiogram in 2009. Therefore, Fig. 2 reports bone conduction thresholds from 2009 for reference). This patient was clearly experiencing great difficulty in communicating in her daily life due to the magnitude of hearing loss bilaterally, poor WRSs, and her subjective indication of minimal benefit provided by the BAHA implanted on her right side.

During this visit, the Cochlear Americas' Intenso™ and Cordelle™ BAHA processors were placed onto the

Table 2. Pure-Tone Bone Conduction Thresholds (dB HL)

	Right						Left					
	Frequency (Hz)											
Year	250	500	1000	2000	3000	4000	250	500	1000	2000	3000	4000
1996	15	30	25**	40	40	40	20	35	40	45	45	40
1998	30	30	30	40	35	35	20	35	45	45	35	40
1999	30	30	25	55	35	45	25	40	45	55	40	45
2000	25	30	25	35	40	50	20	40	40	35	35	30*
2001	25	30	35	40	40	45	20	40	45	35	40	40
2004	20**	20	30	55	50	50	25	45**	40	45	45	30*
2006	25**	30	40	60	55	60*	35	55*	50	55	45*	50*
2007	25**	30**	35	55	50*	50*	25**	55	40*	55	45*	45*
2009	25	30	45	60	60	65	25**	55	45**	55	35	45*

*Could not mask due to limits of the audiometer.

**Could not mask due to magnitude of the air conduction threshold in the nontest ear.

Table 3. Speech Reception Thresholds (SRTs; dB HL) and Word Recognition Scores (WRSs)

	Right		Left	
Year	SRT	WRS	SRT	WRS
1996	45	94%	45	92%
1998	45	92%	50	92%
1999	45	96%	50	92%
2000	50	88%	60	58%
2001	65	86%	60	96%
2004	70	DNT	60	DNT
2006	65	72%	60	74%
2007	70	72%	55	76%
2009	70	68%	55	68%
2011	65	56%	60	54%

Note: DNT = did not test.

abutment on the right mastoid to determine if either would provide an improvement in benefit due to the additional output provided by these devices in comparison to the Compact BAHA processor. The patient, however, did not perceive any significant additional benefit from either device. The authors decided to approach the patient and otologist concerning the option of fitting the severely collapsed left ear canal with a behind-the-ear (BTE) hearing aid. It was agreed from both parties that it would be beneficial to determine whether the patient could achieve significant benefit from this treatment strategy. The patient was medically cleared for a left earmold and hearing aid if an earmold impression could be made, however, it would be extremely difficult to obtain an earmold impression due to the collapsed ear canal. Figure 3A is a video otoscopic photograph that was taken at this visit of the patient's left collapsed ear canal. Figure 3B illustrates the view of the tympanic membrane when the speculum from the video otoscope was inserted into the ear canal. As can be visualized from these photographs, attempting to make an impression of this ear canal for a custom earmold was not a viable option.

Due to the limitations of the left ear canal in making a custom earmold, a noncustom earmold was created using a pediatric immittance tip with 3 mm Libby horn tubing (Fig. 4A). After a considerable amount of practice by the patient, it was possible to insert the noncustom earmold into the ear canal by pulling back and up on the pinna and twisting and turning the immittance tip past the collapsed portion of the ear canal. Due to the success of placing the noncustom earmold into her ear canal, a hearing aid was fit to the left ear.

A Phonak Perseo 211 dAZ hearing aid was fit to the left collapsed ear canal with the noncustom earmold utilizing real ear insertion gain (REIG) measures. A probe tube from a probe microphone of a Frye 7000 hearing aid analyzer was inserted into the left ear canal so the tip of the probe tube was no greater than 6 mm from the tympanic membrane. The real ear unaided gain (REUG) was measured using a DigiSpeech speech weighted signal presented at 65 dB SPL (lower curve of Fig. 5). As can be seen in the lower curve of Figure 5, the REUG has a peak of approximately 20 dB at around 2500 Hz. Also reported in the upper curve in Figure 5 is the National Acoustic Laboratories' nonlinear fitting procedure, version 1 (NAL-NL1) prescriptive target (Byrne et al, 2001) corrected for channel summation and the magnitude of the air-bone gaps. The prescribed REIG for a 65 dB SPL input level was between 14 and 50 dB at 250 to 4000 Hz. The REIG was measured to the prescribed NAL-NL1 target for a soft (50 dB SPL; Fig. 6A), comfortable (65 dB SPL; Fig. 6B), and loud (80 dB SPL; Fig. 6C) input level. The lower curve in each figure of Figure 6 represents the measured real ear aided gain (REAG), and the upper curve reports the resulting measured REIG using a DigiSpeech speech weighted signal from

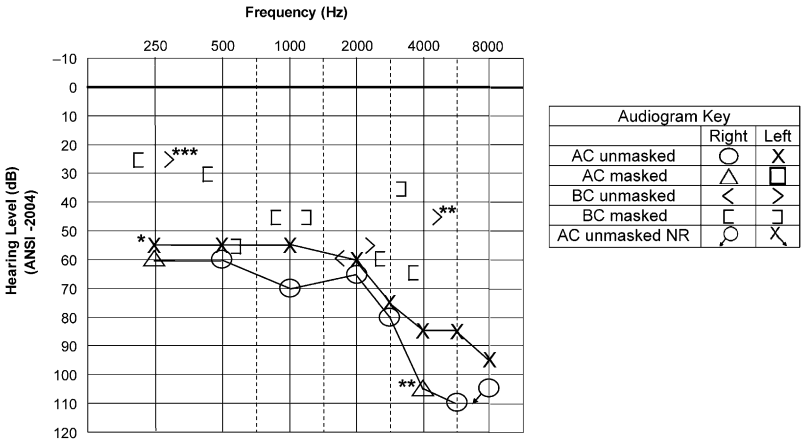

Figure 2. Air conduction thresholds obtained in 2011 and bone conduction thresholds obtained in 2009. (Note that bone-conduction threshold testing was not performed at this visit due to no significant changes in air conduction thresholds from the previous audiogram in 2009. Therefore, this figure reports bone conduction thresholds from 2009 for reference.) *Could not mask due to magnitude of the air-bone gap in the nontest ear; **Could not mask due to limits of the audiometer; ***Could not mask due to magnitude of the air conduction thresholds in the nontest ear; AC = air conduction; BC = bone conduction; NR = no response.

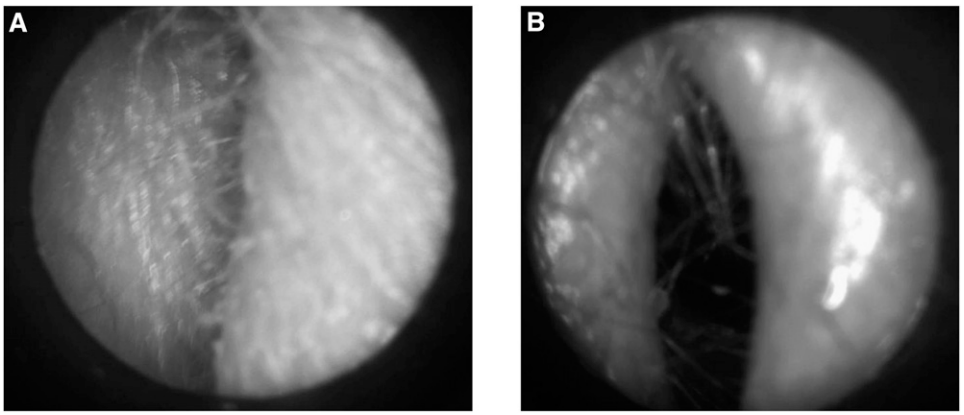

Figure 3. *(A)* Otoscopic photograph of the severely collapsed anterior-posterior left ear canal and *(B)* with the speculum inserted into the ear canal revealing the tympanic membrane.

the Frye 7000. Note the good agreement between the measured and prescribed NAL-NL1 REIG for an input level of 50 dB SPL for the frequencies of 400 to 800 Hz and 1500 to 2500 Hz; at 65 dB SPL for the frequencies of 400 to 4000 Hz; and at 80 dB SPL for the frequencies of 400 to 3000 Hz. The overall gain was reduced by 2 dB in response to patient report that the amplified sound was too loud and the fit was saved to the hearing aid. In addition, no feedback was present, and the patient expressed her ability to clearly hear the conversation of the authors. The patient was counseled on the use and care of the hearing aid and earmold, and as mentioned previously, a considerable amount of time was spent demonstrating the insertion and removal of the hearing aid and earmold. At the conclusion of the fitting, the patient was scheduled to return in 1 wk for follow-up.

FOLLOW-UP VISITS

At the first follow-up appointment, the patient reported that she was having little success with the hearing aid due to difficulty inserting the earmold and that the earmold was uncomfortable when worn for long periods of time. However, the patient reported the hearing aid provided significant benefit when she was able to insert the earmold. Due to patient motivation to try another coupling option, the authors created another

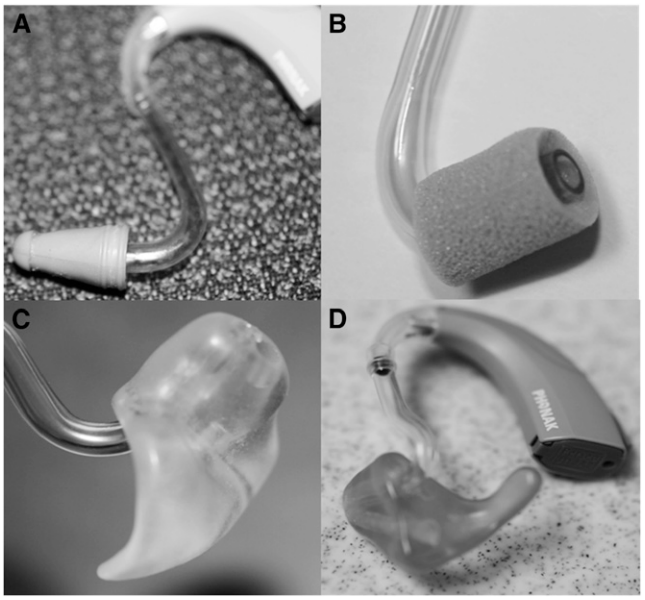

Figure 4. *(A)* Earmold consisting of a pediatric immittance tip and 3 mm Libby horn tubing; *(B)* earmold consisting of an ER-3A pediatric insert earphone and 3 mm Libby horn tubing; *(C)* stock earmold and #13 single bend tubing; and *(D)* stock earmold with a canal lock and #13 double bend tubing.

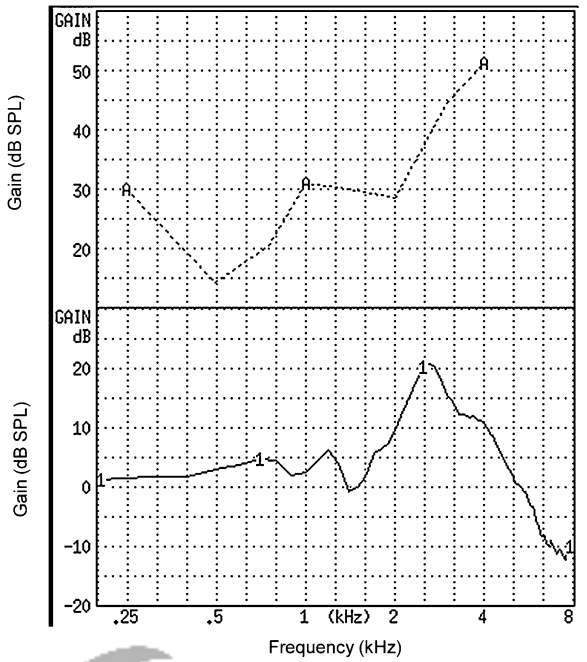

Figure 5. Measured REUG *(lower curve)* and prescribed NAL-NL1 REIG for a 65 dB SPL input *(upper curve)*.

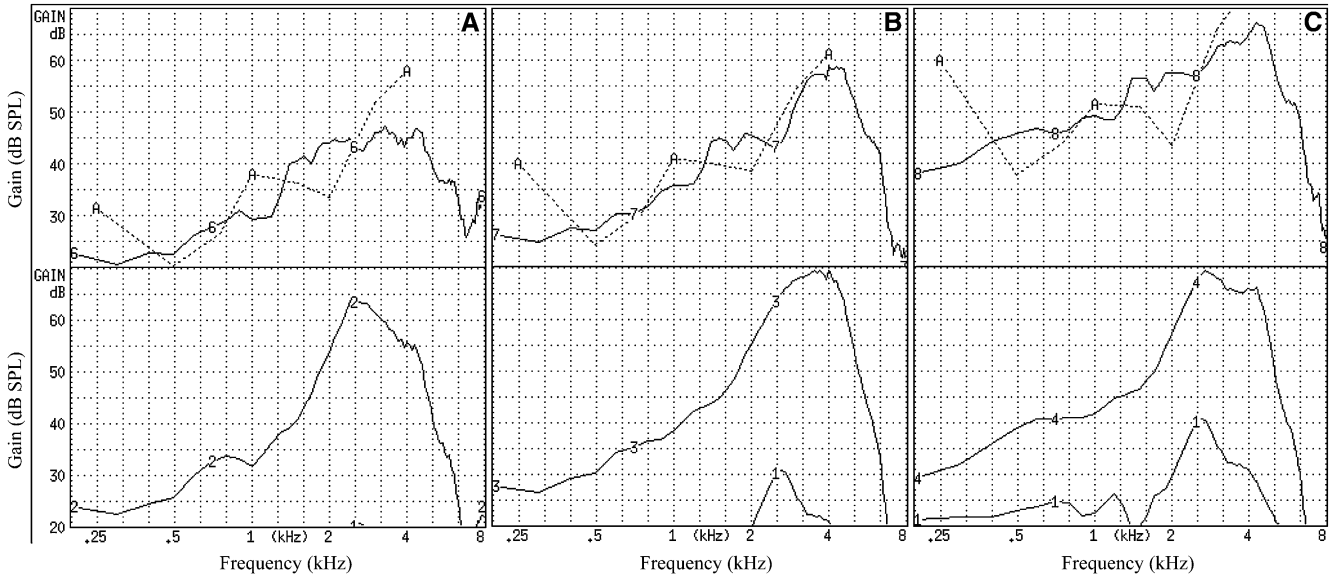

Figure 6. Measured and prescribed REAG *(lower curve)* and REIG *(upper curve)* for a 50 *(A),* 65 *(B),* and 80 *(C)* dB SPL DigiSpeech speech weighted signal.

noncustom earmold consisting of a 3 mm Libby horn connected to an ER-3A pediatric insert earphone with the insert tube removed and the 3 mm Libby horn tubing inserted (Fig. 4B). It was felt this design would be less obtrusive and easier for the patient to insert; however, after numerous attempts by the authors and patient, the noncustom earmold would not stay securely in her ear canal. The next solution was to examine the division's supply of extra earmolds to find a potential fit for her ear canal. These extra earmolds were previously worn by patients and were donated as loaners for use with loaner hearing aids and were cleaned and disinfected via an ultrasonic cleaner. A half shell earmold with a short canal was found that fit snuggly to her ear canal (Fig. 4C). The patient was instructed on insertion and removal of the earmold and hearing aid and was scheduled to return in 1 wk to determine if this approach was more successful than the previous approach.

At the next follow-up, the patient again stated that the new earmold and hearing aid did not stay securely

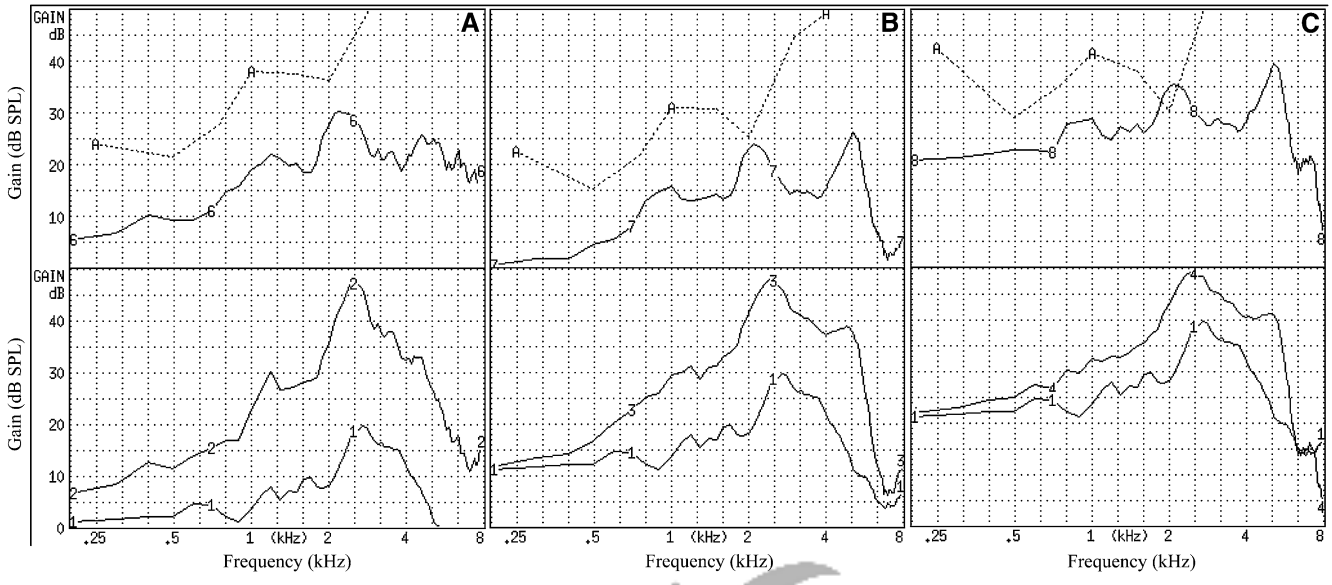

Figure 7. Final REAG *(lower curve)* and REIG *(upper curve)* for a 50 *(A),* 65 *(B),* and 80 *(C)* dB SPL DigiSpeech speech weighted signal.

on her ear; however, when the hearing aid and earmold did stay in her ear canal she reported significant benefit from the hearing aid. Another earmold was found that had a long canal lock and a short canal (Fig. 4D), and it was connected to the hearing aid. The addition of the canal lock provided greater retention of the hearing aid and earmold. The canal portion of the earmold was ground and buffed slightly to provide greater comfort, and the patient was re-instructed on insertion and removal of the earmold and scheduled to return in 1 wk. After 1 wk, the patient reported she was still experiencing difficulty with the earmold staying in her ear canal. It was noted that the tubing was pulling the hearing aid off her ear because the tubing was angled away from the head. The tubing was changed from a #13 single bend tube to a #13 double bend tube, which provided a slightly better fit, but the hearing aid still did not fit snuggly behind her ear. To resolve this problem, the tubing was reshaped by straightening a paper clip and guiding it through the tubing. Then, using a hairdryer to heat the tube, it was reshaped to angle the tubing closer to the patient's head so that in turn the hearing aid would fit closer to the head. After this modification, the hearing aid fit snuggly against the patient's head, and another follow-up appointment was made for 1 wk.

At this visit, unlike the previous visits, the patient wore the hearing aid to the appointment. She reported the changes made to the tubing at the previous visit allowed the hearing aid to stay securely behind her ear. Significant benefit was reported with the hearing aid in combination with her BAHA, and she was able to hear people across the room, whereas she could not hear them before with her BAHA alone. She still struggled in background noise and reported that occasionally she had to turn the hearing aid off due to the overwhelming intensity of background noise.

REIG measures were performed and are reported in Figure 7. The REIG is significantly reduced for a 50 (Fig. 7A), 65 (Fig. 7B), and 80 (Fig. 7C) dB SPL DigiSpeech speech weighted signal in comparison to the NAL-NL1 target. However, when the REIG was closer to the NAL-NL1 target (Fig. 6 A–C), the gain provided by her hearing aid was too loud. The patient was counseled extensively on the discrepancies between the current preferred gain and the original prescribed gain. She was also counseled that this discrepancy may be related to the many years since she wore amplification in the left ear and that our goal was to slowly increase the gain to more closely match NAL-NL1 target so she would be able to obtain the greatest amount of benefit with the hearing aid. A second program was added to help with background noise so she would be able to wear the hearing aid in noisy environments.

FINAL VISIT

The patient returned after 3 mo of wearing the hearing aid in her left ear. She reported having difficulty keeping the earmold in her ear canal, and she returned the hearing aid as she did not want to pursue further coupling options. She was counseled on the newer models of the BAHA, including the BP3^{TM} and the new power model of the Ponto Pro^{TM}, as options to help her hear better than with her current BAHA in quiet and noisy environments. She decided not to pursue these options at that time. Approximately 1 mo later she consulted with her otologist, who discussed the possibility of a meatoplasty so she could wear a hearing aid in her left ear, but the patient opted to forego surgery at that time.

CONCLUSION

In this case report, several options for coupling a hearing aid to a severely collapsed ear canal were presented. All of these options may be viable solutions for a patient with a collapsed ear canal depending on his or her anatomy of the ear canal, which can dictate the comfort of the fitting. As can be seen, fitting amplification on a collapsed ear can presents a unique challenge when trying to couple the hearing aid to the ear canal. Several visits may be required, and patience and persistence by the patient and audiologist is necessary. Although in the end, the patient did not find a coupling option that was successful for her, it is the hope of the authors that this case study will provide coupling solutions for other patients who present with this unique anatomical challenge.

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