Hearing Aid Fittings in Fenestrated Ears: Two Case Studies

Sharon A. Lesner
School of Communicative Disorders
The University of Akron

Fenestrations are operations which were performed to improve hearing loss due to otosclerosis. The operations consisted of creating an opening into the ampulla of the lateral semi-circular canal. Due to the surgical alterations of the outer and middle ear, the volume of the middle ear cavity and resonance pattern of the ear change dramatically. Satisfactory hearing aid fittings in such cases can be problematic. This paper describes the amplification experiences of two individuals with fenestrated ears. The use of real ear probe tube measures, functional gain measures, and programmable hearing aids are highlighted.

The fenestration operation was performed in order to restore hearing loss resulting from otosclerosis. Historically, the introduction of fenestrations represented the turning point in otology from an interest in surgery to deal with infection to interest in reconstructive surgery (Shambaugh, 1967).

Derived from the French word "fenestra," or window, the operation consists of surgically creating another opening to the inner ear. The first fenestration procedure, reported by Passow in 1897, consisted of drilling a hole in the middle ear promontory, thereby providing an alternative avenue for sound to reach the cochlea rather than through the fixated stapes. A simplified one stage procedure was reported in 1938 by the French otologist Lempert (Meyerhoff & Paparella, 1991). The one stage procedure was popular in the United States through the early 1950s.

Lempert's procedure consisted of removing the incus and the head and neck of the malleus and then drilling a fenestra over the ampulla of the lateral semicircular canal. The opening was covered with a skin flap from the meatus which was attached to the upper edge of the tympanic membrane (Shambaugh, 1967).

The basic principle of the operation is that a sound pathway to the labyrinth is created that provides air-conducted sounds a means, other than through the fixated stapes, to reach the inner ear. The average fenestral opening is 1 by 3 mm, which is the same size as the oval window (Shambaugh, 1967). Due to

the loss of the impedance matching mechanism of the ossicular chain, a residual hearing loss of about 25 dB in the speech frequency range typically remains (Shambaugh, 1967).

Fewer fenestrations were performed after Rosen (1953) introduced the stapes mobilization procedure. Stapedectomies, which originated with Schukneckt in 1960 and were popularized by Sheehy (Meyerhoff & Paparella, 1991) became the treatment of choice for otosclerosis. Fenestrations are no longer done for otosclerosis, except in the rare instance when stapedectomies cannot be done. This may include cases when the oval window is absent or when the facial nerve completely covers the oval window (Meyerhoff & Paparella, 1991).

Although fenestrations are no longer routinely performed, some individuals who have had the operation are now experiencing mixed hearing losses due to the overlay of presbycusis. Because of the surgical alterations of the ear, patients with fenestrations present unique hearing aid fitting challenges that may not be evident when only audiometric configuration is considered.

Hearing aids, both custom and non-custom, are designed for acoustically average ears. Surgically-altered ears, however, are quite different than normal, with larger residual volumes and changes in resonance patterns. The residual volume is the remaining ear canal volume between an earmold and the eardrum. As this cavity gets larger, the SPL in the cavity drops (Libby, 1987). The greater residual volume results in an overall reduction in SPL delivered by the hearing aid to the inner ear (Moryl, Danhauer, & DiBartolomeo, 1992). Ear canal resonance tends to occur at lower frequencies in surgically-altered ears (Civantos & Meyer, 1990). The insertion loss, or loss of this natural amplification that occurs when an earmold is placed into the ear, needs to be compensated for in addition to the loss of hearing (Madsen, 1986). Insertion gain optimization is difficult, therefore, due to the large residual volume and the insertion loss that occurs, usually in the range of 1500 to 2500 Hz.

The purpose of this paper is to highlight the experiences of two individuals who used hearing aids in their fenestrated ears. The unique fitting problems that result from the surgical alteration of the ear are highlighted.

CASE REPORTS

Patient A

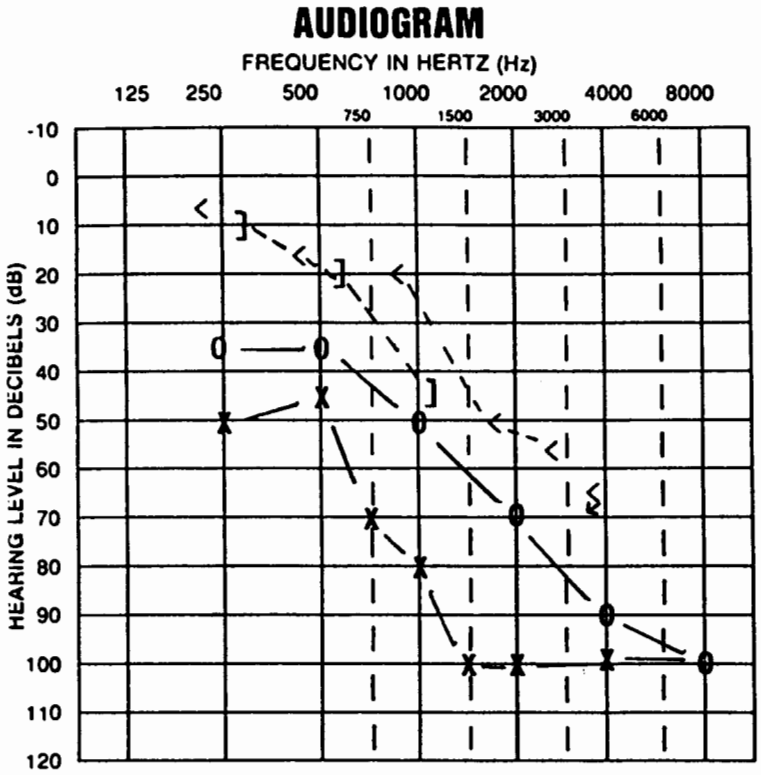
Patient A is a 75-year-old woman who was diagnosed as having bilateral otosclerosis at age 33. She underwent a fenestration of the right ear in 1953 at age 35. Prior to the operation, she had been treated unsuccessfully for her hearing loss with nose drops.

Following the fenestration, the patient was hospitalized for 3 weeks. Severe vertigo followed the surgery to the point that the patient was unable to drive for 4 months because the angular movements of the head necessary to look from side to side were sufficient to induce vertigo. To this day, rapid side to side movements of the head in the lateral plane cause vertigo. Due to desquamated

skin, the ear must still be regularly cleaned out.

Hearing improved in the fenestrated ear following the surgery. The patient underwent three stapes mobilizations in the non-fenestrated ear during the late 1950s. The first was successful for 2 years. The second was not successful and the third worked for 1 year. The patient began wearing a hearing aid in the non-fenestrated ear in 1963, at age 44.

The patient was still aided monaurally when first seen by the author in 1987. Despite being urged to try a hearing aid in the fenestrated ear, the patient de-



	PTA	SRT	WR
Right	55	60	64%
Left	78	75	86%

Figure 1. Audiometric results from Patient A. The right ear is the fenestrated ear.

clined, citing a fear that the hearing aid would induce vertigo and the earmold impression might damage the ear. In addition, the patient had been told by her surgeon in 1953 that "No hearing aid would help the fenestrated ear." She was fit with an Oticon E38P in her non-fenestrated ear.

By 1991, the patient was experiencing more difficulty hearing. At this time, she became friends with an otologist who encouraged her to consider a stapedectomy in her left ear. He would only consent to do the surgery if the fenestrated ear could be satisfactorily aided. The patient agreed to try a hearing aid.

Audiometric results. Results of pure tone audiometric testing indicated a mixed mild-to-severe hearing loss in the fenestrated ear and a mixed severe-to-profound hearing loss in the left ear (see Figure 1). Word recognition results obtained using Auditech recordings of NU-6 word lists were poor (64%) in the right ear and good (86%) in the left ear.

Amplification. Several trial behind-the-ear aids were coupled to the fenestrated ear with a shell earmold. The patient's initial assessment was that none of the hearing aids were providing any benefit. An examination of probe-tube microphone measures obtained using the Fonix 6500 Quick Probe system substantiated this impression.

The Real Ear Unaided Response (REUR) is shown in the first panel of Figure 2. As a result of the enlarged middle ear cavity, the resonance pattern of the fenestrated ear is significantly altered. Two peaks are evident in the REUR including one of 28 dB at approximately 2000 Hz and a second of 14 dB at approximately 4000 Hz.

The effect of the insertion loss is evident in the Real Ear Insertion Response (REIR) measures shown in the second panel of Figure 2 when a trial Oticon E38P was coupled to the ear with the patient's shell earmold. The settings of the Oticon, as well as all of the other trial hearing aids used in these case studies, were modified as much as possible to approximate insertion gain targets. The darker line is the insertion gain target, which was calculated using the patient's own canal response data, and the lighter line is the REIR provided by the hearing aid.

Note the obvious dip in REIR at 2000 Hz and a less prominent dip at 4000 Hz. These dips correspond to the resonant frequencies of the ear. Conventional hearing aids are designed for "average ears" and cannot deliver sufficient gain to overcome the insertion loss that results in the altered ear, especially at 2000 Hz. The responses shown in Figure 2 were obtained with NAL targets. It is important to note that NAL targets need to be adjusted for additional gain in cases of mixed hearing losses (Byrne & Dillon, 1986) and profound losses (Byrne, Parkinson, & Newall, 1991). If these modifications had been reflected with the probe microphone display, it would be even more obvious that the responses of the conventional hearing aids were inappropriate. The same type of pattern resulted when a Unitron UE10 was coupled to the ear with the same shell earmold. The REIR obtained with an Ensoniq ESS is shown in the last panel of Figure 2.

The ESS is a digitally programmable hearing aid system with a 13-band equalizer. The 13 bands can be individually programmed to deliver desired gain. The ESS is an input compression aid and the MPO of the hearing aid is calculated as part of the computer algorithm. The ESS provided the closest approximation to the NAL target and was subjectively the only aid that the patient felt was providing any benefit. Even with the ESS, however, insertion

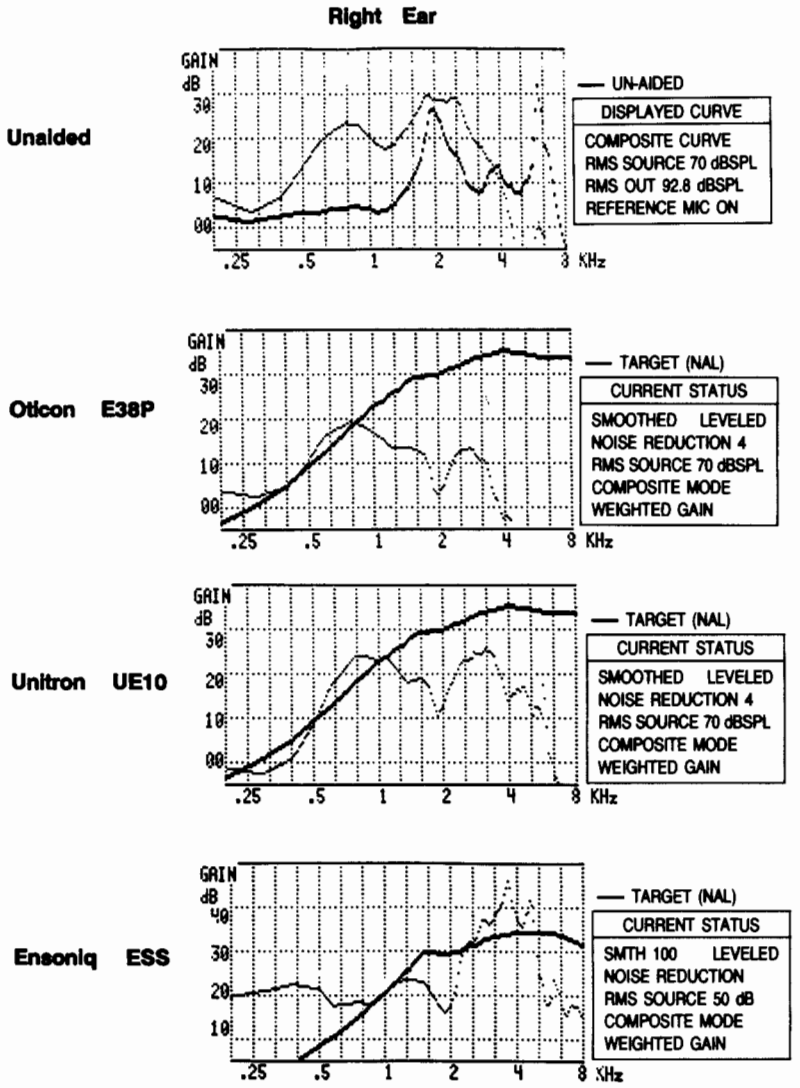


Figure 2. Real ear probe measures of Patient A's fenestrated ear. Dark tracings reflect insertion gain target values and lighter tracings are real ear aided response.

gain target values were not matched well and further modifications were not possible since the hearing aid was operating at the extremes of its range.

Despite being motivated to try new hearing aids and assistive devices, the patient wore the ESS on an infrequent basis. She is currently experimenting with the use of the Unitron US80-S Digitally Programmable hearing aid. The probe measures from the Unitron are shown in Figure 3. The patient has reported that the Unitron is a "more powerful" hearing aid than the Ensoniq and that subjectively, the Unitron provides more benefit. Because of the smoother response and the lack of peaks in the frequency response, patients frequently report that the Ensoniq ESS sounds less powerful than other aids.

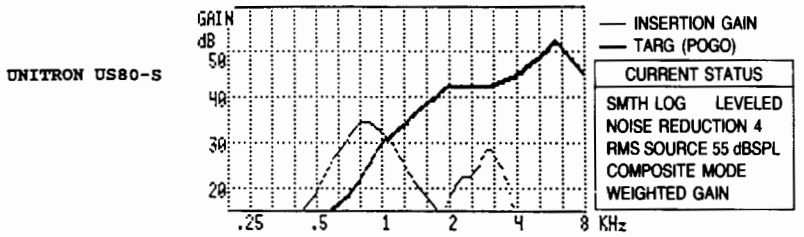


Figure 3. Real ear probe measures of Patient A while wearing a Unitron US80-S in the fenestrated ear. The dark tracing reflects insertion gain target values and the lighter tracing is the real ear aided response.

Patient B

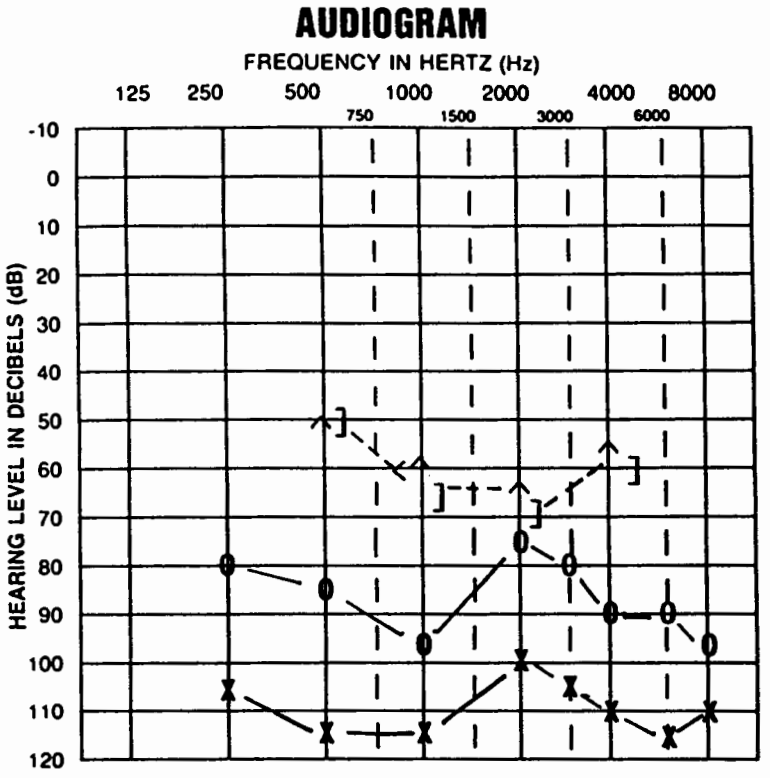
Patient B is a woman, aged 72, who was diagnosed as having otosclerosis at age 18. The patient underwent several different procedures, including a post-nasal resection, tonsillectomy, and "vapor treatment" without any improvement in hearing function.

A fenestration was performed on her right ear in 1947 at age 26. Following surgery, she experienced severe vertigo for 6 months, but this problem eventually subsided. An improvement in hearing resulted from the surgery and the patient was able to function without amplification until 1983. At that time, she was fit with an in-the-ear hearing aid in the fenestrated ear and she reported that she benefitted from the use of the hearing aid. In 1992, she obtained an Audibel in-the-ear hearing aid. She reported that she was neither satisfied with, nor benefitted from the use of the hearing aid. It was at that time that she was seen by the author.

Audiometric results. Results of pure tone audiometry indicated a severe-to-profound mixed hearing loss in the right (fenestrated ear) and a mixed profound hearing loss in the left ear (see Figure 4). Word recognition scores obtained using Auditech recordings of CID W-22 word lists were poor (62%) in the fenestrated ear and could not be tested due to insufficient output of the audiometer in the left ear.

Amplification. The Fonix 6500 Quick Probe system was used to obtain real ear measures. As shown in the first panel of Figure 5, Patient B also has a lower than average resonance frequency, with a peak of 12 dB just below 2000 Hz and a second peak of 12 dB just below 4000 Hz.

The REIR obtained with the patient's Audibel in-the-ear hearing aid is shown in the second panel of Figure 5. The patient had complained that this hearing aid made everyone sound like "Donald Duck." In addition, she complained that the hearing aid made her own voice "echo" and she was overly aware of words with /s/ and /ʃ/ sounds in them. She also complained that she could not turn



	PTA	SRT	WR
Right	85	85	62%
Left	110	CNT	CNT

Figure 4. Audiometric results from Patient B. The right ear is the fenestrated ear.

the volume of the hearing aid up sufficiently without experiencing feedback.

The reason for the patient's complaints are obvious from the REIR. The hearing aid was providing insufficient gain, except between about 3000 and 4000 Hz. In addition, an obvious dip in the insertion gain is evident at just below 2000 Hz with another, less obvious dip present just below 4000 Hz. The dips correspond to the ear's resonance frequencies and reflect the insertion loss that

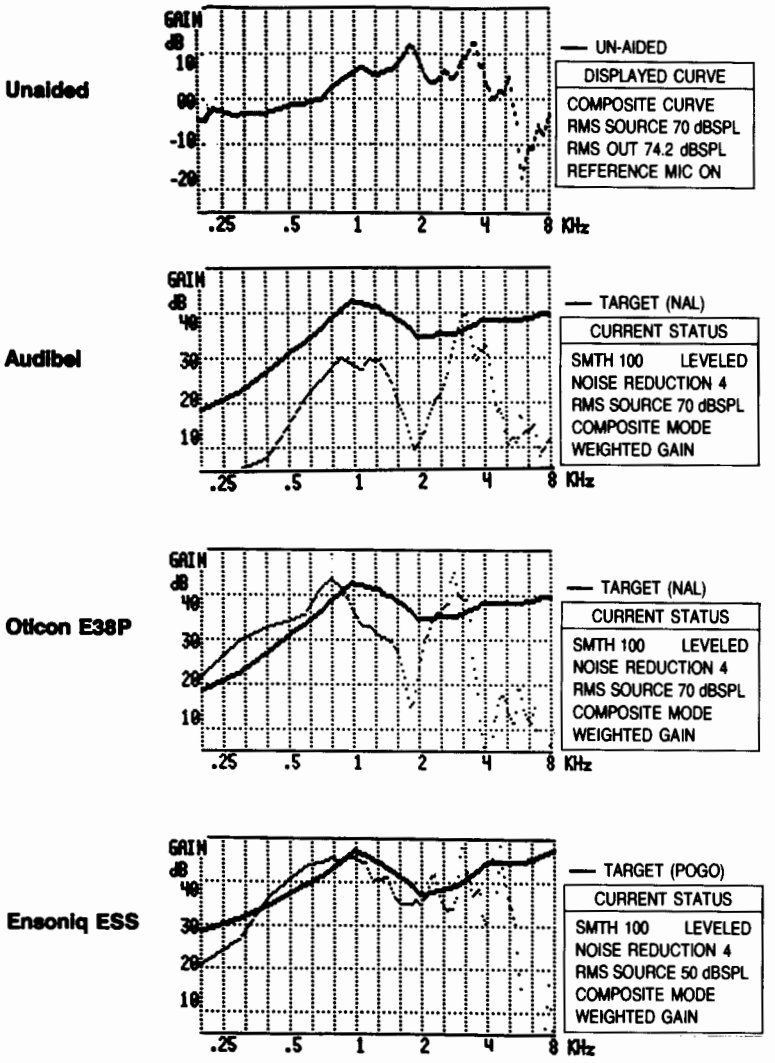


Figure 5. Real ear probe measures of Patient B's fenestrated ear. Dark tracings reflect insertion gain target values and lighter tracings are real ear aided response.

occurs when the ear is occluded.

The significant effect of insertion loss is also highlighted in the REIR obtained when an Oticon E38P was coupled to the fenestrated ear as a trial aid. Notice the same obvious dips in insertion gain just below 2000 Hz and 4000 Hz in the next panel of Figure 5.

The final panel of Figure 5 was obtained with an Ensoniq ESS BTE. With the programmable hearing aid, the insertion loss could be overcome and sufficient sound pressure could be provided. The patient preferred the ESS programmed for POGO. In addition, because the ESS has an input compression circuit, it was necessary to make real ear measures with a 50 dB SPL input, compared to the 70 dB SPL input used with the two other hearing aids which did not have compression circuits operational.

Because some question remains about the validity of real ear probe measures in surgically-altered ears, functional gain measures were also obtained (Hawkins & Mueller, 1992). Aided and unaided thresholds were obtained in the soundfield at a distance of 1 m from the speaker using warble tones. Thresholds were determined using steps of 1 dB. Functional gain and insertion gain measures are shown in Table 1. Note that the measured functional gain agrees with insertion gain, except at 3000 Hz where a difference of 10 dB exists. Considering the variability associated with both the psychoacoustic measures as well as the probe measures, the agreement is impressive.

Table 1

Insertion Gain and Functional Gain Measures of Patient B While Wearing the Ensoniq ESS

Frequency	Real Ear Insertion Gain	Functional Gain
250	24	26
500	41	41
750	44	43
1000	45	41
2000	36	34
3000	34	24
4000	30	33

The patient has been wearing the ESS for several months. Both the patient and her family have reported that they are very pleased with the performance of the hearing aid.

COMMENT

Both of these cases involving surgically-altered ears highlight the inadequacy of relying on threshold measures obtained under earphones and 2-cc coupler

measures in fitting hearing aids. Based solely on audiometric data, both patients would appear to be good candidates for conventional amplification. As a result of the fenestrations, however, the two patients had lower canal resonant frequencies. This is consistent with other reports involving ears with perforations (Moryl et al., 1992) and mastoidectomies (Civantos & Meyer, 1990). The two surgically-altered ears also had larger residual volumes.

Patient A had a resonance of 28 dB at approximately 2000 Hz and a second resonant peak of 14 dB at approximately 4000 Hz. She was difficult to fit because of the pronounced resonances and the resulting insertion loss. Patient B also had lower than normal ear canal resonances (12 dB at 2000 Hz and 12 dB at 4000 Hz), but could be fit because the insertion loss was not as great.

Conventional hearing aids, which are designed for normal ears, cannot typically provide sufficient amplification to overcome the insertion loss at the lower than average resonant frequency of the surgically-altered ear. In addition, the greater residual volume requires greater overall gain. Either functional gain measures or insertion gain, which is the electroacoustic counterpart of functional gain, should be made in order to assess the changes that result from the surgical procedure. Needed modifications of the amplification system can then be made accordingly.

High gain and MPO are typically needed for mixed losses, consequently feedback will be problematic with customized ITEs. Simply sending the manufacturer real ear probe microphone measures and expecting that a suitable customized ITE will be fabricated is not very likely. The flexibility of programmable BTE hearing aids, such as the Ensoniq ESS, is, however, particularly desirable in such cases.

Because of the trauma that resulted from the fenestration procedure, post-surgical concerns still persist in the two patients described here. Both patients were apprehensive about having earmolds made and about potential infection of the ear resulting from the use of earmolds. Although hearing aids should always be provided within a comprehensive program of auditory rehabilitation, supportive counselling was particularly needed to encourage use of amplification and to optimize the fitting of these two individuals with fenestrated ears.

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