Efficacy of Hearing Aid Repairs by Manufacturers and by Alternative Repair Facilities

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Hearing aids typically malfunction at some time during their usable life span. A person with impaired hearing who buys his first aid should learn how to detect malfunction in his aid, how to obtain adequate repair service, and how to seek verification that the aid has been repaired to meet his needs. It is particularly important that such information be conveyed to the parents of a child with impaired hearing. The child may have neither the awareness nor the resources to seek help for a malfunctioning or inadequately repaired aid. During early language acquisition, even a brief period of time spent using a malfunctioning aid, an inappropriate loaner, or no aid at all during repair may represent a considerable setback for the child. The amount of time during which a hearing aid malfunctions is minimized when the owner knows how to seek efficient repair service and to evaluate the quality of repair. Unfortunately, little information regarding the efficacy of hearing aid repairs has been available for the consumer.

While monitoring the electroacoustic characteristics of children's hearing aids, Zink (1972) found that 60 (58%) of 103 hearing aids needed repair during one year. Porter (1973) reported that 37 (45%) of 82 aids worn by children in a state school for the deaf were sent for repair during a single school year, and that six of these aids required repair more than once during the year. Although data regarding the proportion of adult-worn aids requiring repair each year is less accessible, Ewertsen (1972) has reported that 12,500 (18%) of all hearing aids in use in Copenhagen needed repair during a single year.

In the traditional hearing aid delivery system, the owner of a malfunctioning aid takes it to the hearing aid dealer from whom he purchased the instrument. The dealer checks the aid for easily fixed dysfunctions such as obstruction or leakage in the acoustic coupling between the aid and the ear. If the repair will involve opening the case of the aid, the dealer mails it to the manufacturer's repair facility. Upon completion of repairs, the aid is returned to the dealer who then gives it back to the hearing aid user.

Not all major hearing aid repairs are performed by the manufacturer of the instrument. One alternative is for the hearing aid dealership to provide repair service within the local office. In this way, the dealer may sometimes be able to offer more prompt and less expensive repairs than the manufacturer, avoiding shipping damage and shipping charges. A second alternative to the use of the manufacturer's repair facility has developed in recent years with the growth of independent repair laboratories. A hearing aid dealer, an audiologist, or a hearing aid user may send an aid to an independent repair laboratory and may receive service at lower cost than repairs performed by the manufacturer. Repairs performed at an independent laboratory may even be accompanied by a new warranty. Of course, if a malfunctioning hearing aid is still covered by the original factory warranty, a first-time repair would be provided free by the manufacturer but not by the independent repair laboratory.

Few repair facilities provide the results of electroacoustic testing of the repaired aid to the dealer. Few dealers have the electroacoustic test equipment to verify that the repaired aid is functioning properly. The owner of the aid must combine his own listening skills with blind faith to determine that the aid has been repaired and is operating in "like-new" condition. Both clinical experience and data from Zink (1972) suggest that the electroacoustic characteristics of some repaired aids show substantial deviations from those specified by the manufacturer for that model. Zink examined 52 repaired aids to determine whether they met the following criteria for acceptability of repair: gain and maximum power output within 6 dB of specifications or meeting the requirements of the user; frequency response free of transient increases or decreases exceeding 15 dB or having fewer than two such spikes exceeding 6 dB; harmonic distortion not exceeding 17% at any one frequency; and gain control taper not so nonlinear as to interfere with the user's performance. On the basis of these criteria, 18 (35%) of the repaired aids were considered to be unacceptable, with the largest number of repaired aids failing on the basis of frequency response or both frequency response and harmonic distortion.

Most aids are mailed to the repair facility with a description of the complaint but without explicit instructions as to the desired electroacoustic characteristics. Occasionally an aid may need a specific modification in order to suit the amplification needs of the user. For example, an aid may require the removal of a sharp peak in the basic frequency response or in the saturation curve. Kasten and Braunlin (1970) documented a case where a specified hearing aid modification required that the instrument be returned to a prominent hearing aid manufacturer five times in order that the change be made correctly.

Existing data and clinical experience have suggested the need for evaluation of the hearing aid repair system. Accordingly, a study was undertaken in our clinic laboratory to determine the efficacy of repair of hearing aids by different repair facilities. Electroacoustic characteristics of 41 hearing aids were measured immediately following repair by the manufacturers, by independent repair laboratories, or by a repair facility in the office of a local hearing aid dealer. Basic frequency response, full-on average gain, and saturation sound pressure level for each aid were compared with the values specified by the manufacturer for the same model. The purposes of the study were to determine the proportion of hearing aids functioning at or near manufacturer's specifications when returned to their owners, and to compare the efficacy of repairs performed by the manufacturers as opposed to repairs performed by alternative repair facilities.

METHOD

The electroacoustic characteristics of 37 repaired hearing aids were examined. Four of the 37 instruments were two-channel body level aids. Each of these four instruments was treated as two separate aids, bringing the total number of repaired aids to 41.

Twenty-one of the 41 aids were made by one manufacturer, while the remaining 20 aids were distributed almost equally among five other manufacturers. Of the 41 aids, 16 (39%) were body-level, 14 (34%) were behind-the-ear, and 11 (27%) were eyeglass-type aids. Eighteen (44%) of the 41 aids belonged to clients of the Institute of Logopedics or of the Wichita State University Hearing Clinic. The remaining 23 (56%) of the aids belonged to the clients or to the stocks of two hearing aid dealerships. Twenty-three (56%) of the 41 aids were repaired by the manufacturers' repair facilities. Eighteen (44%) of the aids were repaired at alternative repair facilities. Of these 18 aids, nine were repaired by one independent repair laboratory, two were repaired by a second independent repair laboratory, and seven were repaired in the office of a local hearing aid representative. None of the aids were sent to the repair facility with a special instruction to modify the aid in any way which would cause it to deviate from manufacturer's specifications for that model.

Each aid was examined within two days after notification that it had been returned from repair, before it was worn or returned to the owner. Because of the way in which most of the aids were obtained for the study, few aids were available for pre-repair analysis. Audiological data were not obtained for the owners of the repaired hearing aids, so it was not possible to determine whether a repaired aid met the owner's amplification needs even when it did not meet manufacturer's specifications.

Electroacoustic characteristics of each repaired aid were measured using the comparison method in a conventional Bruel and Kjaer hearing aid measurement system, composed of a hearing aid test box (Type 4212), sine-random generator (Type 1024), microphone amplifier (Type 2603), audio frequency spectrometer (Type 2112), and graphic level recorder (Type 2307). Immediately before each aid was measured, the system was calibrated and the flatness of its frequency characteristics was verified to meet the criteria established by the American National Standards Institute (ANSI, 1960). In addition, for any hearing aid with a frequency response extending below 200 Hz, the input sound pressure level of the system was verified to remain constant within ± 1.5 dB at least to the lower limit of the frequency response for that aid.

For each repaired hearing aid, the following measurements were performed: basic frequency response, full-on average gain (HAIC gain), and saturation sound pressure level (HAIC SSPL), all expressed according to ANSI (1967) and the Hearing Aid Industry Conference (HAIC, 1961). Although it would have been desirable to report the harmonic distortion of the repaired aids, many specification sheets provided by the manufacturers did not report harmonic distortion and no basis of comparison for efficacy of repair was available. In order to facilitate comparison between repaired aids and manufacturer's specifications, great care was taken to measure each aid under the same conditions as those reported in the specifications provided by the manufacturer for that model. When the specifications were incomplete regarding such conditions as battery, tubing size, tubing length, tone control settings, or receiver, the manufacturer was contacted in order to obtain the information.

The manufacturer's HAIC gain specification was subtracted from the HAIC gain of the repaired aid to obtain a deviation score in decibels for the gain measurement. In the same manner, the manufacturer's HAIC SSPL specification was subtracted from the HAIC SSPL of the repaired aid to obtain a deviation score in decibels for the SSPL measurement. The lower limit of the manufacturer's specified basic frequency response was subtracted from the basic frequency response of the repaired aid, and the upper limit of the manufacturer's specified frequency response was subtracted from that of the repaired aid, resulting in two deviation scores in Hz for frequency response for each aid.

RESULTS

One of the 41 aids displayed internal feedback when the gain control was set to a level sufficient to take any of the electroacoustic measures. Hence, the gain, SSPL, and frequency response of this aid, which had been repaired by the local hearing aid representative, could not be included in the analysis. A second aid, repaired by its manufacturer, displayed gross distortion in a simple listening check and obviously would require further repair before it could be used. Four additional aids were repaired more than once within a two-month period, having been repaired inadequately the first time. For example, one of these four instruments came back from an independent repair laboratory completely dead, having a loose gain-control wheel with unlimited rotation; the electroacoustic characteristics of this aid were measured and included in the analysis after further repair. In all, then, at least six (15%) of the original 41 aids required more than one trip to the repair facility within a very short period of time to achieve even basic operation. Only one of the six aids which were known to need repeated trips to the repair facility had been repaired by the manufacturer. The other five had been repaired at alternative facilities. Only 40 of the 41 aids could be included in further analysis because the aid with internal feedback was not available for measurement after further repair.

Arbitrarily, it was decided that an acceptably repaired hearing aid was one whose electroacoustic characteristics conformed to manufacturer's specifications for an aid of the same model, within these tolerances:

1. HAIC gain within ±6 dB of specifications;
2. HAIC SSPL within ±6 dB of specifications;
3. lower limit of HAIC basic frequency response within 100 Hz of specifications; and
4. upper limit of HAIC basic frequency response within 500 Hz of specifications.

It should be pointed out that these tolerances are actually more lenient than those listed in the proposed ANSI standard for hearing aid characteristics (Anonymous, 1976).

Gain. The mean absolute deviation of the gain of 40 repaired aids from their manufacturer's specifications was 4.7 dB (s.d. 3.7 dB). Twenty-six (65%) of the aids had less gain and 14 (35%) had more gain than specifications. Thirteen (32%) of the 40 aids deviated no more than 3.0 dB in either direction from the gain specified by the manufacturer. Twelve (30%) of the aids differed by more than 6.0 dB and three (8%) differed by more than 10.0 dB from their specified gain. The greatest gain deviation score for a single aid was 15.7 dB.

Saturation Sound Pressure Level. The mean absolute deviation of the SSPL of the 40 repaired aids from their manufacturer's specifications was 2.6 dB (s.d. 2.0 dB). Two (5%) of the aids deviated 0 dB from specifications, while 29 (72%) of the aids had a lower SSPL and nine (23%) had a higher SSPL than specifications. Twenty-seven (68%) of the 40 aids deviated no more than 3.0 dB in either direction from the SSPL specified by the manufacturer. Only two (5%) aids differed by more than 6.0 dB from their specified SSPL. The greatest SSPL deviation score for a single aid was 8.1 dB.

Frequency response. For each aid two frequency response deviation scores were computed, one for each end of the HAIC basic frequency response. The mean absolute deviation of the low cutoff of the frequency response of 40 repaired aids from manufacturer's specifications was 48 Hz (s.d. 46 Hz). One aid deviated 0 Hz from specifications, while 19 (48%) aids had frequency responses extending lower than specifications and 20 (50%) did not extend as low as specifications. Twenty-six (65%) of the aids deviated by no more than 50 Hz from the manufacturer's specified value for the lower limit of the frequency response. Only three (8%) of the aids differed by more than 100 Hz from their specified lower limit. The greatest deviation score for a single aid was 235 Hz at the low end of the frequency response.

The mean absolute deviation of the high cutoff of the HAIC basic frequency response from manufacturer's specifications was 406 Hz (s.d. 433 Hz). Eight (20%) of the aids did not deviate from specifications, while 19 (48%) had frequency responses which did not extend as high and 13 (32%) extended higher than specifications. Seventeen (42%) of the 40 aids deviated by no more than 200 Hz from the manufacturer's specified value for the upper limit of the frequency response. Eleven (28%) aids differed by more than 500 Hz from their specified upper limit. The greatest deviation score for a single aid was 2100 Hz at the high cutoff of the frequency response.

Proportion of acceptable repaired aids. Sixteen (39%) of the original 41 aids were repaired acceptably according to the criteria established for this investigation. One of these 16 aids, however, had required more than one trip to the repair facility within a week for the same complaint and therefore its performance was acceptable only after the second repair. Thus only 15 (37%) of 41 repaired hearing aids matched manufacturer's specifications, within the arbitrary tolerances listed above, after only one repair for a particular malfunction.

For the 40 aids whose electroacoustic characteristics could be measured, 24 (60%) failed on the basis of one or more criteria. Of these 24 aids, nine (37%) failed solely on the basis of the gain measurement and 11 (46%) failed on the basis of frequency response cutoffs only. The remaining four (17%) of the 24 aids failed on a combination of criteria (see Table 1).

Comparison among repair facilities. Because of the small and uneven number of hearing aids repaired by each manufacturer and by each alternative repair facility, statistical analysis of repair efficacy among the individual facilities was not felt to be warranted. However, a breakdown of the 16 acceptably repaired aids by repair facilities (see Table 2) shows that, of 23 aids repaired by four different manufacturers, nine (39%) met the repair criteria. Of 18 aids repaired by three different alternative, non-manufacturer repair facilities, seven (39%) met the repair criteria; one of these seven met the criteria only after more than one repair for the same complaint.

Table 1. Number of aids failing to meet each repair criterion.*

Criterion		Number of aids failing to meet criterion
Gain only (±6 dB of specs.)		9
SSPL only (±6 dB)		1
Frequency response only (±100 Hz at low end, ±500 Hz at high end.)		11
Gain and SSPL		0
Gain and Freq. Response		2
SSPL and Freq. Response		0
Gain, SSPL and Freq. Response		1
	TOTAL	24

*24 of 40 aids whose electroacoustic characteristics could be measured failed to meet one or more criteria. The electroacoustic characteristics of a 41st aid could not be measured due to internal feedback.

Table 2. Distribution of 16 acceptably repaired aids among repair facilities*

		Manufacturer of Aids						Subtotal By Repair Facility
		#1	#2	#3	#4	#5	#6	
Repaired By Manufacturer		7/10	1/5	1/4			0/4	9/23
Repaired By Alternative Facility	Local	1/7**						1/7
	Indep. #1	2/3			2/4	2/2		6/9
	Indep. #2	0/1				0/1		0/2
Subtotals By Manufacturer		10/21	1/5	1/4	2/4	2/3	0/4	16/41

*Each fraction is the number of acceptably repaired aids over the rotal number of repaired aids for that facility.

**This one aid required more than one repair to meet criteria of acceptability.

DISCUSSION

Only 15 of 41 malfunctioning hearing aids approximated manufacturer's specifications after one trip to a repair facility. This finding has implications for the counselling of the hearing aid user. Before paying for an expensive repair, or accepting a free repair for an aid under warranty, the owner of a hearing aid should find means to verify that the aid functions according to specifications and meets his amplification needs. If the hearing aid owner has the slightest doubt as to the quality of a repair job, he should take the aid to a facility having electroacoustic test equipment to verify that the aid works appropriately or to document the need for further repair. Ideally, all repaired aids should be measured electroacoustically both at the repair facility and at the time they are returned to the owner, following the possibility of damage during shipping from an out-of-town repair facility to the owner (Cooper, 1975).

For several reasons, only limited conclusions can be drawn regarding comparative efficacy of the different repair facilities. It would have been desirable to have a copy of electroacoustic measurements on each instrument at the time when it was new. Kasten, Lotterman, and Revoile

(1967) demonstrated that a new aid may deviate considerably from specifications in its gain-versus-frequency characteristics, and several new aids of the same model may differ markedly among themselves. Zink (1972) also reported that many new aids fail to meet manufacturer's specifications. It is possible that an aid considered to be inadequately repaired for the present investigation actually achieved a "like-new" condition for that specific instrument, which never did meet manufacturer's specifications. If the aid, when new, had met the amplification needs of the user without meeting manufacturer's specifications, then a repair back to its original condition would satisfy the owner.

Because few of the aids in the study belonged to long-term clients of the clinic in which the study was performed, data was incomplete regarding date of purchase and earlier repair history for some of the aids. It is possible that the hearing aids repaired by manufacturers were newer, on the average, than aids repaired by alternative repair facilities. A relatively new aid still under factory warranty would be returned to the manufacturer for early free repairs rather than being sent to an alternative repair facility, which would charge for the first repair.

The results of this study suggested no differences in efficacy of repair of hearing aids by manufacturers versus alternative repair facilities. However, the finding that less than half of the repaired aids approximated manufacturer's specifications, and that several aids required repeated trips to achieve operational condition, suggests that hearing aid owners must seek verification for the quality of repairs regardless of the repair facility used. Audiology clinics possessing electroacoustic test equipment should maintain records of hearing aid performance for each instrument when new, when malfunctioning, and when repaired, in order to give the hearing aid user meaningful information regarding the performance of his personal amplification system.

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