

# Intraindividual Comparison of the Bone-Anchored Hearing Aid and Air-Conduction Hearing Aids

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**Background:** Some patients have to stop using their air-conduction hearing aid(s) because it causes or exacerbates chronic otitis. Then, a solution is the use of a bone-conduction hearing aid such as the percutaneous bone-anchored hearing aid (BAHA).

**Objective:** To compare patients' performance with their previous air-conduction hearing aid(s) and their BAHA using audiometric tests and a questionnaire.

**Design:** Prospective clinical evaluation in a single subject design.

**Patients:** The results of 34 consecutive patients from the Nijmegen, the Netherlands, BAHA series were included. The patients had bilateral conductive or mixed hearing loss and chronic ear problems. Before the BAHA was fitted, the patients used air-conduction hearing aids.

**Results:** The results of the speech recognition in noise test showed a small but significant improvement with the BAHA. This improvement was related to the size of the air-bone gap. The greater the air-bone gap, the poorer the results with the air-conduction hearing aid(s). The questionnaire demonstrated that the majority of patients preferred the BAHA; diminished occurrence of ear infections played a significant role. The patients did not express an evident preference concerning speech recognition.

**Conclusions:** In patients with chronic ear problems a BAHA is an acceptable alternative if an air-conduction hearing aid is contraindicated. Preoperative assessment of the size of the air-bone gap is of some help to predict whether speech recognition may improve or deteriorate with the BAHA compared with the air-conduction hearing aid.

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**B**ONE-CONDUCTION hearing aids have been in use since the 18th century.<sup>1</sup> Generally, a bone-conduction hearing aid is considered inferior to an air-conduction hearing aid because of its often clumsy appearance, poor frequency response, and inadequate gain.<sup>2,3</sup> Therefore, bone-conduction hearing aids are only fitted to patients if problems arise with air-conduction hearing aids, such as chronic otitis media, chronic otitis externa, or congenital atresia of the ear canal. Surprisingly, few authors<sup>3</sup> have made an audiometric comparison between conventional bone-conduction hearing aids and air-conduction hearing aids.

In the 1980s, a percutaneous bone-conduction hearing aid called the bone-anchored hearing aid (BAHA) was developed in Sweden.<sup>4</sup> It is composed of a percutaneous titanium implant anchored in the temporal bone and a spe-

cially designed bone-conduction transducer with amplifier that is attached to the implant by means of a bayonet coupling. Several studies have been conducted in which the patients' performance with the BAHA was compared with that with their previous conventional air-conduction hearing aid. Performance with the BAHA was found to be superior in some patients and inferior in others. Therefore, on average, minor improvements or no changes at all were found.<sup>5-12</sup> So far, no satisfactory explanation has been found for this ambiguity. We investigated a large number of patients (N=34) with the aim of making a better comparison and wider search for significant parameters that might be useful for counseling patients. For this purpose, free-field thresholds, speech recognition in quiet, and speech recognition in noise data were evaluated that had been obtained with the individually fitted air-conduction hearing aid and BAHA. Pos-

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## PATIENTS AND METHODS

### PATIENTS

The patient group included 34 consecutive BAHA users (22 women and 12 men) who had previously been fitted with air-conduction hearing aids. Blockage of the ear canal with the ear mold of the air-conduction hearing aid had caused or exacerbated chronic otitis with symptoms such as otorrhea, itch, unpleasant smell, and pain. Therefore, the patients were advised to discontinue using this device. All patients had conductive or mixed hearing loss. Twelve patients (35%) were fitted with linear, medium power, behind-the-ear hearing aids (full-on gain on 2-mL coupler at 0.5, 1, and 2 kHz between 35 and 50 dB sound pressure level; maximum output level at the same frequencies is between 113 and 121 dB sound pressure level). Their pure tone average at 0.5, 1, 2, and 4 kHz varied from 25 to 65 dB hearing level (HL). The other patients were fitted with linear, high-power, behind-the-ear hearing aids (full-on gain between 51 and 70 dB sound pressure level; maximum output is between 125 and 133 dB sound pressure level). Their pure tone average ranged from 40 to 90 dB HL. Because of the chronic ear problems, several of the patients had vented ear molds. Only 5 of the 34 patients had been fitted binaurally.

All patients received the BAHA monaurally. At the end of the trial period of 6 to 8 weeks, all patients used their BAHA on a daily basis. Two patients stopped using the BAHA after 3 months and 2.5 years of use, respectively. Both patients experienced pain when using the BAHA; no explanation for the complaints was found.

The average age of the patients was 48 years (range, 26-72 years). Fifteen patients (44%) had 1 totally deaf ear. The pure tone average for air-conduction thresholds at 0.5, 1, 2, and 4 kHz varied from 25 to 90 dB HL (mean, 60 dB HL). The pure tone average for bone-conduction thresholds at the same frequencies varied from 6 to 46 dB HL (mean, 26 dB HL). The air-bone gap varied from 11 to 54 dB HL (mean, 34 dB HL). These data refer to the ear ipsilateral to the side of implantation that was always the ear with the best cochlear reserve. In all patients, the surgery was uneventful.

### METHODS

Special attention was paid to the evaluation of the previously fitted air-conduction hearing aids. From free-field measurements, the functional gain was determined. To see whether the functional gain was adequate, it was compared with the calculated gain according to the well-known National Acoustic Laboratories' rule.<sup>13</sup> Originally, this rule was developed for sensorineural hearing loss. If an air-bone gap is present, the calculated gain at each frequency is adapted proportional to the size of the air-bone gap at that frequency.<sup>13</sup> Since bone-conduction thresholds were not routinely determined at 0.25 kHz, and in several of the patients the bone-conduction threshold at 8 kHz was outside the range of the audiometer, the comparison

between measured and calculated gain values was performed at 0.5, 1, 2, and 4 kHz.

To make a comparison between the patients' performance with their individually fitted BAHA and their former air-conduction hearing aids, free-field aided thresholds and speech recognition in quiet and in noise were determined. Before testing, the previous as well as the new hearing aids were checked for normal functioning and were adjusted by the patients to their preferred setting. The tests and the measurement protocol have been described in detail elsewhere.<sup>10,11</sup> The tests were carried out with the old device prior to the BAHA fitting and with the new device 4 to 6 weeks after the fitting of the BAHA.

From the measured free-field speech recognition-intensity function (speech audiogram), the maximum score (maximum phoneme score [MPS]) was derived.<sup>10</sup> To quantify speech recognition in noise, the speech in noise (S/N) ratio was determined according to the criteria of Plomp and Mimpen<sup>14</sup> at a fixed noise level of 65 dB. The intrasubject SD of this test is 1 dB; thus, a change in S/N ratio that exceeds 2 dB ( $2 \times SD$ ) can be considered statistically significant. In this study, a difference in excess of 1.4 ( $2/\sqrt{2}$ ) dB between 2 S/N ratios was regarded as significant because the S/N values used in the analyses were the average values from 2 successive measurements. In principle, the S/N ratio and the MPS are independent of the volume setting (gain level) of the hearing aids.

A 2-tailed Student *t* test was applied to analyze differences in the results between the BAHA and the air-conduction hearing aids. Statistical significance was set at the .05 level. The significance of a change in the MPS was verified using the critical differences based on the assumption that the speech recognition score behaves as a binomial variable.<sup>15</sup>

All patients were invited to complete a questionnaire to obtain long-term subjective information concerning ear infections, frequency of visits to the ear, nose, and throat outpatient clinic (related to draining ear or problems with the BAHA), handling, and feedback. Additionally, hearing aid-related aspects, such as speech recognition in quiet and in noisy surroundings, quality of the sound, and cosmetic appearance, were addressed. The questionnaire had been sent to the patients recently after a period of BAHA use that varied from 9 months to 7 years (mean, 32 months). The patients were asked to express their preference for the previous air-conduction hearing aids or the BAHA. Furthermore, the patients indicated which aspects they considered to be the most important advantage and disadvantage of the BAHA compared with the air-conduction hearing aids. Also, questions were answered about taking care of the implant and about which type of hearing aid they preferred overall (the questionnaire is presented in **Table 1**). Since a long duration of follow-up may have biased the results of the questionnaire regarding speech recognition, a comparison was made with the results of a previously administered short-term follow-up questionnaire filled out 5 months after the BAHA fitting.<sup>16</sup> Only 11 of the patients had filled out the previous questionnaire. The results of the 2 questionnaires were compared.

sible relations between the results and audiometric parameters recorded before surgery were examined to see whether these relations, if present, might have predictive value regarding improvement or deterioration in a

patient's speech perception performance with a BAHA. Additionally, the patients' preference for the BAHA or air-conduction hearing aid was evaluated by means of a questionnaire.

**Table 1. Questionnaire\***

1. Which hearing aid is better with regard to
  - A. The occurrence of ear infections  
Air-conduction hearing aid  BAHA  No difference
  - B. Speech recognition in quiet places  
Air-conduction hearing aid  BAHA  No difference
  - C. Speech recognition in noise surroundings  
Air-conduction hearing aid  BAHA  No difference
  - D. Sound quality  
Air-conduction hearing aid  BAHA  No difference
  - E. Visibility  
Air-conduction hearing aid  BAHA  No difference
  - F. Handling  
Air-conduction hearing aid  BAHA  No difference
  - G. Feedback problems  
Air-conduction hearing aid  BAHA  No difference
  - H. ENT visits  
Air-conduction hearing aid  BAHA  No difference
2. On which of these hearing aid-related aspects A to H does the BAHA distinguish itself most from the previous hearing aid in a positive sense?
3. On which of these hearing aid-related aspects A to H does the BAHA distinguish itself most from the previous hearing aid in a negative sense?
4. Do you regard cleansing of the implant and the surrounding skin as a burden? (yes/no)
5. In general, which hearing aid do you prefer?  
Air-conduction hearing aid  BAHA  No difference

\*BAHA indicates bone-anchored hearing aid; ENT, ear, nose, and throat outpatient clinic.

## RESULTS

### GAIN PROVIDED BY THE AIR-CONDUCTION HEARING AIDS

**Table 2** presents the outcome of the comparison between the measured functional gain and that calculated by the National Acoustic Laboratories' rule (see the "Patients and Methods" section). On average, at 0.5 and 1 kHz, the measured gain was significantly lower than the calculated gain. However, at 2 kHz it was significantly higher, while at 4 kHz there was no difference. Next, per patient the difference between measured and calculated gain was determined, averaged over the 4 frequencies. This average difference value, averaged over all patients, was not significantly different from zero (Table 2, last line). In 6 patients (18%), the average difference exceeded -10 dB (range, -11 to -16 dB). Thus, the measured gain was more than 10 dB lower than the calculated gain. In 3 cases this was ascribed to a mismatch of more than 20 dB at 0.5 kHz because of the use of vented ear molds. Excluding these cases, it was concluded that in 3 patients the air-conduction hearing aid fitting was questionable.

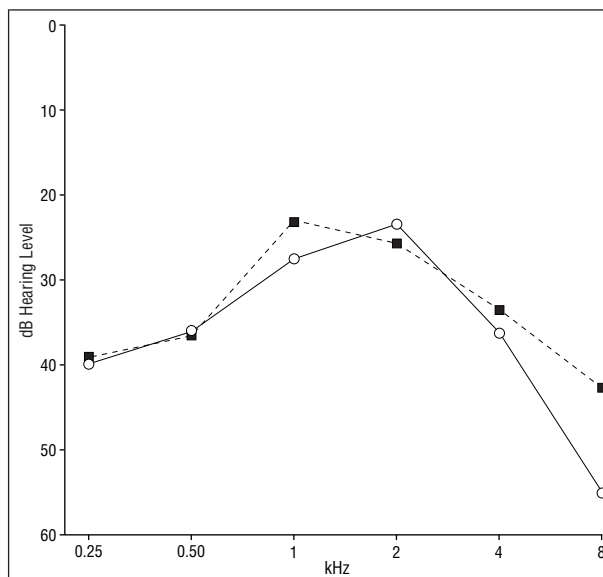
### COMPARISON BETWEEN BAHA AND AIR-CONDUCTION HEARING AID

The mean free-field thresholds (and SDs) of the 34 patients, obtained with the air-conduction hearing aids and with the BAHA, are shown in **Figure 1**. When the mean values were compared, a significant difference was found

**Table 2. Difference Between the Calculated and Measured Functional Gain and *t* Test Results\***

Frequency, kHz	Mean (SD), dB	<i>t</i>	<i>P</i>
0.5	-6.7 (11.1)	3.52	.002
1	-5.0 (10.9)	2.67	.01
2	3.2 (7.8)	2.39	.02
4	-1.4 (11.6)	0.70	.70
Average	-2.7 (8.0)	1.93	.07

\*N=34.

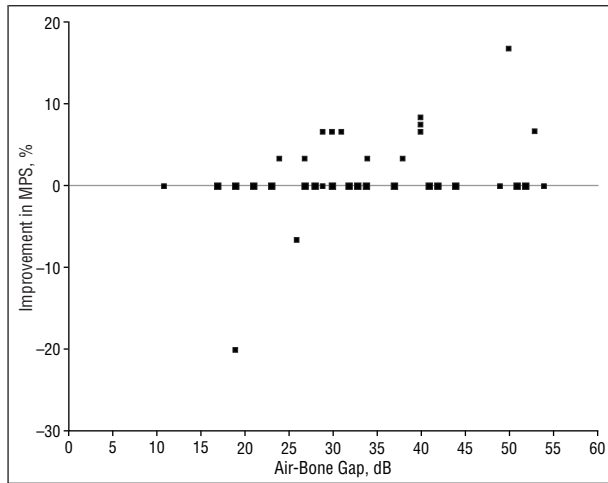


**Figure 1.** Mean aided thresholds with the bone-anchored hearing aid (dashes) and the air-conduction hearing aid (solid line) at different frequencies (n=34). The SD (not indicated) for the air-conduction hearing aid thresholds varied between 11.9 dB at 2 kHz and 21.3 dB at 8 kHz and for the bone-anchored hearing aid between 8.3 dB at 1 kHz and 22.3 dB at 8 kHz.

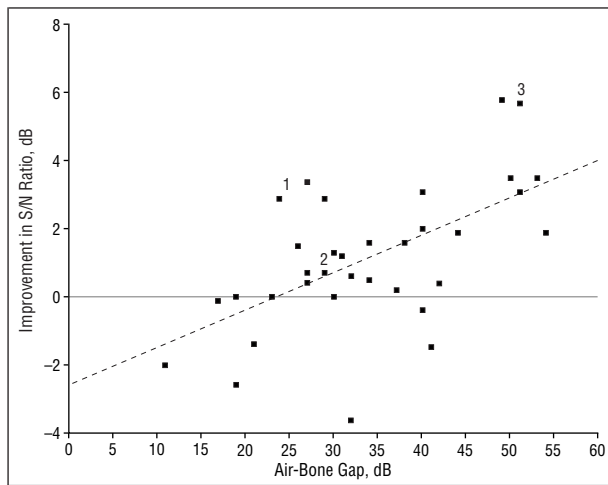
in favor of the BAHA at 1 kHz ( $t=3.53$ ;  $P<.01$ ) and 8 kHz ( $t=5.65$ ;  $P<.001$ ) of 6 and 12 dB, respectively.

On average, no significant difference in MPS was found between the BAHA and air-conduction hearing aids (mean±SD difference, 1.0%±5.4%). This finding was obscured by the fact that 16 of the 34 patients obtained an MPS of 100% with both types of hearing aid. According to the critical difference (see the "Patients and Methods" section), the MPS of 6 patients improved significantly with the BAHA, while in 3 patients it deteriorated significantly. **Figure 2** shows the change in MPS plotted against the size of the air-bone gap (average air-bone gap at 0.5, 1, 2, and 4 kHz). In patients with an air-bone gap that exceeded 30 dB, the MPS with the BAHA was equal to or better than that with the air-conduction hearing aid. The 3 patients in whom the air-conduction hearing aid fitting was judged as questionable did not show a significant change in the MPS, which is comparable with the results of most of the other patients.

On average, the improvement in S/N ratio between the BAHA and air-conduction hearing aid(s) was a mean (±SD) of 1.1±2.1 dB. This reflects a small but significant change with the BAHA ( $t=3.17$ ;  $P<.01$ ). When the 1.4-dB criterion was used on an individual basis (see the "Patients and Methods" section), the S/N ratio with the BAHA



**Figure 2.** Maximum phoneme score (MPS) obtained with the bone-anchored hearing aid minus that obtained with the air-conduction hearing aid (change in MPS) plotted against the width of the air-bone gap (N=34). The large squares indicate the results of the patients whose score was 100% with both types of hearing aid.

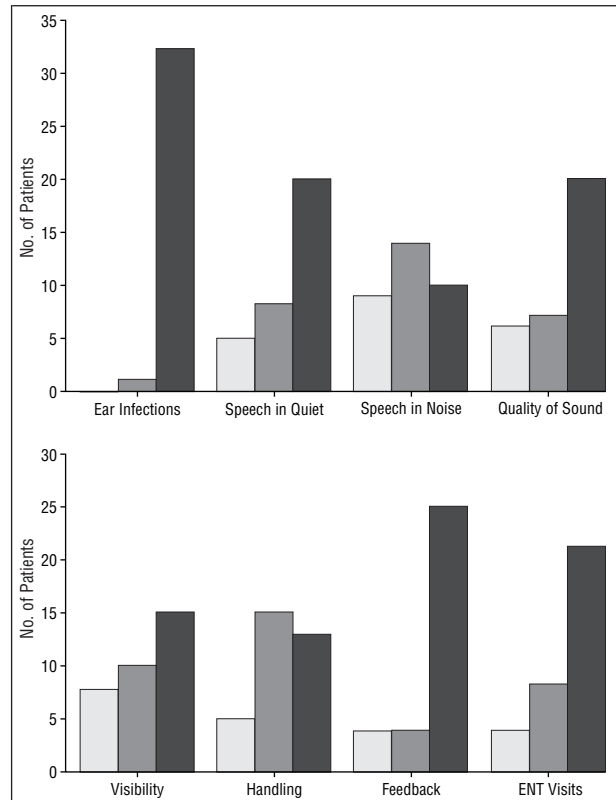


**Figure 3.** Improvement in the speech-to-noise ratio (S/N ratio) with the bone-anchored hearing aid vs the air-conduction hearing aid, plotted against the width of the air-bone gap (N=34). Dashes represent the calculated regression line. Data points of 3 patients with a questionable air-conduction hearing aid fitting are numbered 1 to 3 (see the "Results" section).

improved significantly in 15 patients, it did not change in 14 patients, and it deteriorated significantly in 5 patients.

Using the preoperative data, no significant correlation was found between the change in the S/N ratio and either the (average) bone-conduction thresholds or (average) air-conduction thresholds. However, a significant correlation was found between the change in S/N ratio and the width of the air-bone gap ( $r=0.59$ ;  $P<.01$ ); this relation is illustrated in **Figure 3**. The regression line is indicated and it crosses the line  $y=0$  at 24.4 dB. In only 2 of the 28 patients whose air-bone gap exceeded 25 dB, the S/N ratio deteriorated significantly with the BAHA. Fifteen of these 28 patients showed significant improvement.

In **Figure 3**, the data of the 3 patients in whom the air-conduction hearing aid fitting was judged as questionable are numbered 1 to 3. Two of these 3 patients



**Figure 4.** Results of the questionnaire. The number of patients who preferred the previous air-conduction hearing aid (light-shaded), the bone-anchored hearing aid (black bar), or neither (medium-shaded) regarding several hearing aid-related aspects (n=33). ENT indicates ear, nose, and throat outpatient clinic.

show pronounced improvements that may be ascribed to too-low volume settings of their air-conduction hearing aids. Excluding the data points of these 3 patients from the regression analysis did not change the main outcomes. The correlation coefficient remained 0.59 and the newly calculated regression line showed a small, almost parallel shift of 0.3 dB to the right.

All but 1 patient filled out the questionnaire. The results are shown in **Figure 4**. There was a clear preference (>60% of the patients) for the BAHA concerning the (diminished) occurrence of ear infections, speech recognition in a quiet environment, quality of the sound, feedback, and frequency of outpatient visits to the ear, nose, and throat clinic. The distribution of preference was more even concerning speech recognition in a noisy environment, cosmetic appearance, and handling. The majority of patients stated that having fewer ear infections was the most important advantage of the BAHA compared with the air-conduction hearing aids (**Table 3**). There was no obvious most important disadvantage of the BAHA; 11 patients did not respond to any of the 8 potential disadvantages listed. Nine of 33 patients found that taking care of the skin around the implant was a burden. Overall, 27 patients preferred the BAHA, 5 patients preferred the previous air-conduction hearing aid, and 1 patient regarded both hearing aids as equal. Five patients had been fitted binaurally with air-conduction devices. Four of these 5 patients preferred the monaural BAHA to the binaural air-conduction hear-

ing aid; this preference was mainly based on non-hearing factors such as occurrence of ear infections, cosmetics, and ear mold problems.

In 11 patients it was possible to compare their present, long-term (varying from 39-84 months) follow-up questionnaire results on speech recognition with those obtained 5 months after fitting the BAHA. Disagreement was found in only 9% of the answers. Therefore, it was concluded that the long interval between fitting the BAHA and completing the long-term follow-up questionnaire only had a minor effect on a patient's opinions of speech recognition.

### COMMENT

The evaluation of the functional gain of the air-conduction hearing aid fittings showed that there was a close resemblance between the measured gain and the gain prescribed by the modified National Acoustic Laboratories' rule for mixed hearing loss. This suggests that on average the air-conduction hearing aids were fitted adequately. In only 6 patients, the averaged measured functional gain was more than 10 dB poorer than the calculated one. In 3 cases this was ascribed to the use of vented ear molds, so it was concluded that in only 3 patients the air-conduction hearing aid fitting had been questionable. Nevertheless, it should be noted that these 3 patients, just like all the others, adjusted the volume of their hearing aid to the gain level that they regarded as the best during daily use.

Figure 1 shows that in the high-frequency region, the aided thresholds with the BAHA were somewhat better than those obtained with the air-conduction hearing aids. According to the National Acoustic Laboratories' rule, amplification in the high-frequency range with the air-conduction hearing aids was adequate (Table 2). This is an important finding, because research has shown that improvements in high-frequency thresholds result in better speech recognition, especially in noisy surroundings.<sup>17</sup> Indeed, it was found that on average the S/N ratio of our patients was better with the BAHA than with their previous hearing aids. Earlier studies<sup>6-9</sup> did not show such improvements in performance on the speech recognition in noise tests. In the present study, only 4 patients (12%) performed significantly better with the air-conduction hearing aid in the S/N test whereas 15 patients (44%) performed significantly better with the BAHA.

The MPS could not be used to differentiate between the 2 types of hearing aids because almost half of the patients achieved maximum scores with both types of hearing aids. The relationship between a change in MPS and the width of the air-bone gap, as presented in Figure 2, has been obscured by this ceiling effect.

It is of interest to have some way of predicting how patients who are advised to stop using their air-conduction hearing aids will perform with a BAHA. Browning and Gatehouse<sup>9</sup> suggested that preimplantation evaluation of the difference in performance between the air-conduction hearing aid and a temporary conventional bone-conduction hearing aid might have predictive value. However, it must be noted that on average pa-

**Table 3. Most Important Advantage and Disadvantage of the Bone-Anchored Hearing Aid Compared With the Air-Conduction Hearing Aid**

Criteria	No. of Patients
Most important advantage	
Fewer ear infections	27
Better speech recognition in quiet	3
Better speech recognition in noise	1
Better quality of sound	2
No important advantage	0
Most important disadvantage	
Poorer speech recognition in quiet	4
Poorer speech recognition in noise	4
Poorer quality of sound	3
Poorer cosmetic appearance	3
Difficult to handle	3
More feedback	4
More frequent ear, nose, and throat outpatient clinic visits	1
No important disadvantage	11

tients perform significantly better with a BAHA than with a conventional bone-conduction hearing aid.<sup>8,10,12</sup>

A totally different approach to this problem might be to consider the width of the air-bone gap. Based on the fact that hearing by bone conduction is far less effective than by air conduction, the performance of patients with pure sensorineural hearing loss, even with a powerful bone-conduction device, may be poorer than with an air-conduction hearing aid.<sup>18,19</sup> However, in patients with an air-bone gap, as was the case in this study, the amplification of an air-conduction hearing aid needs to be increased substantially, because in contrast with a bone-conduction device (eg, the BAHA), an air-conduction hearing aid has to compensate for (part of) the air-bone gap. This can be a problem because the amplification and output levels of an air-conduction hearing aid are limited, owing to increased susceptibility to feedback and, as with every hearing aid, to possible saturation of the amplifier. Accordingly, as the width of the air-bone gap increases, patients' performance with the air-conduction hearing aid might gradually approach that with the BAHA. At a certain stage, a break-even point might be expected, which, according to Figures 2 and 3, occurs at an air-bone gap of 25 to 30 dB.

According to our evaluation, the majority of patients preferred the BAHA to their previous well-fitted air-conduction hearing aids. Diminution of ear infections and, consequently, fewer visits to the outpatient clinic were important aspects. In addition, the BAHA was popular owing to the quality of the sound and its properties in relation to feedback (Figure 4). Where speech recognition in noisy surroundings was concerned, neither type of hearing aid took preference. The relatively late evaluation of the patients' preference regarding speech recognition may have played a role, but a comparison between the present questionnaire results and those obtained with a short-term questionnaire showed good agreement. This suggests that the long follow-up did not seriously influence the patient's opinion on this subject.

At our clinic, the BAHA is fitted in patients with conductive or mixed hearing loss. First, the indications for

implanting a BAHA are severe problems with a conventional bone-conduction hearing aid fitting, such as pain and inadequate speech recognition. Second, patients with chronic draining ears, despite thorough medical or surgical treatment, who need amplification but cannot bear occlusion by the ear mold of an air-conduction hearing aid are candidates for the BAHA.<sup>8,10,11</sup> For the latter group of patients, it may be concluded that the results of this study indicate that the BAHA is a highly acceptable alternative for air-conduction hearing aids. It remains imperative to inform patients before implantation about possible deterioration in speech recognition, according to our findings, especially if the air-bone gap is smaller than 25 to 30 dB. Thus, our study has provided better candidacy guidelines for potential benefit from the BAHA vs air-conduction hearing aids.

The relatively new BAHA has proved to be an effective hearing aid for patients with chronic otorrhea and it should be considered more often in the treatment of patients with chronic otitis media who need amplification.

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## REFERENCES

- Berger KW. Early bone-conduction hearing aid devices. *Arch Otolaryngol*. 1976;102:315-318.
- Skoda-Turk R, Welleschit B. Air-conduction or bone-conduction hearing aids? comments on hearing aids for sound conduction deafness. *Laryngol Rhinol Otol*. 1981;80:478-483.
- Snik AFM, Mylanus EAM, Cremers CWRJ. Aided free-field thresholds in children with conductive hearing loss fitted with air- or bone-conduction hearing aids. *Int J Pediatr Otorhinolaryngol*. 1994;30:133-142.
- Håkansson B, Tjellström A, Rosenhall U, Carlsson P. The bone-anchored hearing aid: principle design and a psychoacoustical evaluation. *Acta Otolaryngol (Stockh)*. 1985;100:229-239.
- Carlsson P, Håkansson B, Rosenhall U, Tjellström A. A speech-to-noise ratio test with the bone-anchored hearing aid: a comparative study. *Otolaryngol Head Neck Surg*. 1986;94:421-426.
- Lindeman P, Tengstrand T. Clinical experience with the bone-anchored hearing aid. *Scand Audiol*. 1987;16:37-41.
- Bonding P, Holm Jönsson M, Salomon G, Ahlgren P. The bone-anchored hearing aid: osseointegration and audiological effect. *Acta Otolaryngol (Stockh)*. 1992;107(suppl 492):42-45.
- Håkansson B, Liden B, Tjellström A, et al. Ten years of experience with the Swedish bone-anchored hearing system. *Ann Otol Rhinol Laryngol*. 1990;99(suppl 151):1-16.
- Browning GG, Gatehouse S. Estimation of the benefit of bone-anchored hearing aids. *Ann Otol Rhinol Laryngol*. 1994;103:872-878.
- Mylanus EAM, Snik AFM, Cremers CWRJ, Jorritsma FF, Verschuure J. Audiological results of the bone-anchored hearing aid HC200: multicenter results. *Ann Otol Rhinol Laryngol*. 1994;103:368-374.
- Mylanus EAM, Snik AFM, Jorritsma FF, Cremers CWRJ. Audiologic results for the bone-anchored hearing aid HC220. *Ear Hear*. 1994;15:87-92.
- Cooper HR, Burrell SP, Powell RH, Proops DW, Bickerton JA. The Birmingham bone anchored hearing aid programme: referrals, selection, rehabilitation, philosophy and adult results. *J Laryngol Otol*. 1996;110(suppl 21):13-20.
- Byrne D, Dillon H. The National Acoustic Laboratories' (NAL) new procedure for selecting the gain and frequency response of a hearing aid. *Ear Hear*. 1986;7:257-265.
- Plomp R, Mimpen AM. Improving the reliability of testing the speech reception threshold for sentences. *Audiology*. 1979;18:43-52.
- Thornton AR, Raffin MJM. Speech discrimination scores modeled as a binomial variable. *J Speech Hear Res*. 1978;21:507-518.
- Mylanus EAM, Snik AFM, Cremers CWRJ, Jorritsma FF, Verschuure J. The bone-anchored versus the conventional hearing aid: the patients' opinions. *Arch Otolaryngol Head Neck Surg*. 1995;121:421-425.
- Hagerman B. Clinical measurements of speech reception threshold in noise. *Scand Audiol*. 1984;13:57-63.
- Snik AFM, Mylanus EAM, Cremers CWRJ. The bone-anchored hearing aid (BAHA) versus air-conduction hearing aids. In: Portmann M, ed. *Transplants and Implants in Otology III*. Amsterdam, the Netherlands: Kugler; 1996:309-312.
- Snik AFM, Mylanus EAM, Cremers CWRJ. Bone anchored hearing aids in patients with sensorineural hearing loss and persistent otitis externa. *Clin Otolaryngol*. 1995;20:31-35.