On the evaluation of a superpower sound processor for bone-anchored hearing

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Funding information
Cochlear

Objectives: Performance of a superpower bone-anchored hearing aid (Baha), the Baha Cordelle from Cochlear Bone-Anchored Solutions (BCD1), was compared to its successor, the Baha 5 SuperPower (BCD2).

Design: A comparative study in which each patient served as its own control.

Participants: Ten experienced BCD1 users with profound mixed hearing loss. For comparison, data from another study with 10 experienced users with a severe mixed hearing loss using a Cochlear Baha 5 power sound processor (BCD-P) were included.

Main outcome measures: Speech reception thresholds in noise and APHAB and SSQ questionnaires.

Results: Speech reception thresholds for the digits-in-noise (DIN) test were significantly lower (P < 5%), that is more favourable, for BCD2 in the speech and noise frontal condition and in the speech frontal and noise contralateral condition than for BCD1. For the group with severe mixed loss fitted with BCD-P, the SRTs were not significantly different (P > 5%) from the BCD2 values.

With the APHAB questionnaire scores were significantly lower, that is more favourable, for the ease of communication (P < 5%) and the background noise (P < 1%) domains for BCD2 than for BCD1. APHAB scores for the aversiveness of loud sounds domain were not significantly different for both devices (P > 5%). Scores for the speech and quality domains of the SSQ questionnaire were significantly higher, that is more favourable, for BCD2 than for BCD1. APHAB and SSQ scores for BCD-P were not significantly different from those for BCD2 (P > 5%).

Conclusions: Data for BCD2 in profound mixed loss are similar to those for BCD-P and a severe mixed loss. Of 10 patients, 2 expressed a strong preference for BCD2 over BCD1, and 7 patients had a preference for BCD2 over BCD1. One patient preferred BCD1 because of its built-in telecoil facility.

1 INTRODUCTION

Patients with profound hearing loss may experience problems with air-conduction hearing aids due to tightly fitted ear moulds and/or maximum gain restrictions by acoustic feedback. In profound mixed hearing loss consisting of a moderate sensorineural loss and a large air-bone gap, a powerful direct-drive bone-conduction device (BCD) is a viable alternative for a conventional hearing aid, owing to the relatively favourable bone-conduction thresholds.

In essence, a percutaneous BCD system consists of a titanium implant anchored in the temporal bone with a skin-penetrating titanium abutment, and a sound processor. The sound processor converts...
sound into mechanical vibration. The vibrations are transferred through abutment and implant to the skull bone. This direct, percutaneous, transmission of vibration to the skull may provide 10-15 dB more gain and output in the mid and high frequencies than transmission across an intact skin, that is with transcutaneous stimulation.1,2

Until recently, the body-worn bone-anchored hearing aid (Baha) Cordelle II sound processor with a separate transducer (vibrator) from Cochlear Bone-Anchored Solutions (BCD1) was the only option for patients with a profound mixed hearing loss that needed a BCD. The fitting range of BCD1 was estimated suitable for bone-conduction thresholds up to 55 dB HL.3,4 Recently, the Baha 5 SuperPower sound processor (BCD2) was introduced. The BCD2 is also a 2-piece device consisting of a sound processor and a separate vibrator. The sound processor can be worn at ear level, either behind or under-the-ear, but it can also be used as a body-worn (“clip on”) device. In contrast, Cochlear Baha 5 Power (BCD-P) device is an abutment-level Baha in a single casing containing both sound processor and vibrator. BCD-P is a power device suitable for individuals with a severe mixed hearing loss.5 In essence, BCD2 and BCD-P share the same signal processing strategy. They differ only in maximum force output (MFO).

BCD2 and BCD-P offer a more flexible and detailed fitting procedure than BCD1, and they provide (much) more advanced signal processing than BCD1, including a dynamic feedback cancellation system. DeSmet et al6 have shown that digital signal processing may be advantageous over analogue processing in bone-anchored hearing. BCD2 and BCD-P also feature wireless capabilities that may be especially beneficial for this patient population.7-11 At the time of this study, there was no telecoil facility available for BCD2.

In this study, we compared the performance of BCD1 and BCD2 in a group of 10 patients with profound mixed loss. Results were compared with those for 10 patients with severe mixed loss and BCD-P. These latter patients met all inclusion criteria of the current study except for hearing loss. The evaluation comprised both audiological measures and questionnaires.

2 | MATERIALS AND METHODS

Performance of the Baha Cordelle II (BCD1) and Baha 5 SuperPower (BCD2) from Cochlear Bone-Anchored Solutions (CBAS, Mölnlycke, Sweden) was evaluated in a group of 10 experienced BCD1 users. Inclusion criteria were age (<80 years), stable mental condition and bone-conduction thresholds (still) within the fitting range of BCD1. Eight patients were selected from those eligible for replacing the BCD1 after using their device for at least 5 years. Additionally, 2 recently implanted patients were included. These 2 patients underwent a 2-month acclimatisation period with BCD1 before entering the experiments. Each patient served as its own control. For comparison, data from a study with 10 experienced users and a severe mixed loss comparing Baha 5 Power (BCD-P) with BP-110 were included. BCD2 and BCD-P use similar sound processing. The main difference is a 10 dB lower maximum output force level for BCD-P relative to BCD2.

In the experiments, a new BCD1 was used. All patients used BCD1 in its body-worn position on the chest. One patient used BCD2 in the behind-the-ear position at the ipsilateral side of the implant, 7 patients in the under-the-ear position at the implant side and 2 patients used BCD2 in the body-worn position. In the under-the-ear position, the speech processor is worn upside down with both microphones close to the ear lobe. The wearing options were guided both by space requirements, that is the distance between pinna and fixture/abutment position, feedback limitations and user preferences.

Maximum force output levels on a TU-1000 skull simulator12 of both BCD2 and BCD1 are shown in Figure 1A. This figure shows similar MFO values for BCD1 and BCD2 for frequencies below 1 kHz. The MFO for frequencies above 1 kHz is about 10 dB higher than that for BCD1.
for BCD2 than for BCD1. Figure 1B shows the same data in relation to the thresholds for direct bone conduction. These data were obtained by subtracting the RETFL data in Table II (least squares estimate) from the MFO values in Figure 1A.

In all patients, pure-tone thresholds were measured with standard procedures and equipment (Interacoustics Equinox audiometer fitted with TDH39 headphones and B-71 bone conductor).

In the first session, performance with a new BCD1 was evaluated. The settings of the new device were copied from the patient’s own device. The evaluations consisted of measuring free-field aided thresholds and aided speech perception in noise with the DIN test (Smits et al., 2004).

Aided free-field thresholds with BCD1 were measured with 1/3 octave narrow-band noise. Speech perception in noise was measured with the DIN test. In essence, this test focuses on the speech reception threshold in noise (SRT) by presenting triplets of the numbers 0-9 in an adaptive fashion against a background of noise. The noise spectrum was equal to that of the long-time average of the speaker. The level of the noise was fixed at 65 dBA. Speech levels were varied using a simple one up, one-down procedure. After correct repetition of all 3 numbers, the level of the next triplet was decreased with 2 dB, in all other cases, the level was increased with 2 dB. The SRT was calculated from the presentation levels of the last 20 triplets. The SRT was measured in 4 conditions. In the first condition, speech and noise were presented in front of the listener (S0N0). In the other conditions, speech was presented in front of the listener and the noise was presented either from the ipsilateral side of the implant (S0N0), from the contralateral side (S0N90), or from the back of the listener (S0N180). For BCD-P, the S0N180 was considered less relevant and was thus omitted.

Real-life performance was evaluated with the Abbreviated Profile of Hearing Aid Benefit (APHAB), with the Speech, Spatial and Quality of hearing scale (SSQ) questionnaire, and with a proprietary questionnaire based on a visual analogue scale addressing overall speech quality, perception of speech in quiet and in noise, annoyance from ambient noise, and ease of communication.

At the end of the first session, BCD2 was fitted according to the manufacturer’s procedures with minimal manual fine tuning. In 2 cases with poorer bone-conduction thresholds where feedback measurements indicated insufficient stable gain in the head-worn position, BCD2 was used in the body-worn position.

In the second session, after a 4-week acclimatisation period, the same tests were performed, but now with BCD2. When measuring aided-free-field thresholds and speech perception in noise, the noise-reduction algorithm of BCD2 was switched off.

The comparison group of 10 experienced BCD-P users was evaluated with the DIN-test in 3 speech and noise conditions and with APHAB and SSQ questionnaires.

### RESULTS

The unmasked ipsilateral pure-tone thresholds for air conduction and bone conduction of the 10 patients expressed in 25%, 50% (median) and 75% percentiles are shown in Figure 2A. Median bone-conduction values at 0.5, 1, 2 and 4 kHz were 30, 35, 50 and 56 dB HL, respectively. For the BCD-P users, the median bone-conduction thresholds at 0.5, 1, 2 and 4 kHz were 25, 25, 45, 52.5 dB HL, respectively.

The mean aided thresholds for BCD1 and BCD2 are shown in Figure 2B. Paired Student’s t tests with Bonferroni correction for multiple comparisons showed no significant differences between the aided thresholds for BCD1 and BCD2 (P > 5%).

Results for speech perception in noise as measured with the DIN-test are shown in Figure 3. Figure 3 shows a significantly lower signal-to-noise (SNR) ratio of −3.8 dB for BCD2 in the speech and noise frontal (S0N0) condition vs 1.3 dB for BCD1 (P < 5%). In the S0N90 condition, with frontal speech and noise from the rear, the SNRs of BCD1 and BCD2 are not significantly different. This is
also true for frontal speech and noise presented at the ipsilateral side of the implant, the S0N+90 condition. However, in the S0N/C090 condition with frontal speech and noise presented at the contralateral side of the implant, the SNR of 9.1 dB for BCD2 is significantly lower than the SNR of 4.9 dB for BCD1 (P < 5%). The SRTs for the BCD-P users in the S0N0, S0N+90, and S0N-90 conditions are not significantly different (P > 5%) from those for BCD2.

Results for the APHAB questionnaire17 are shown in Figure 4A. Scores for the ease of communication domain are significantly lower, that is more favourable, for BCD2 than for BCD1 (P < 5%). Scores for background noise are also significantly lower for BCD2 than for BCD1 (P < 1%). Score differences for the domains reverberation and aversiveness of loud sounds are not significant at the 5%-level. Scores with BCD-P are not significantly different from those with BCD2 (P > 5%).

Figure 4B shows the results for with the SSQ questionnaire.19 Scores for the speech domain are significantly higher, that is more favourable, for BCD2 than for BCD1 (P < 1%). Scores for the quality domain are also higher for BCD2 than for BCD1 (P < 5%). Scores with BCD-P are not significantly different from those with BCD2 (P > 5%).

In Figure 5, the results of a proprietary questionnaire using visual analogue scales show significantly higher, more favourable, scores for BCD2 than for BCD1 for sound quality, speech perception in quiet and ease of communication (P < 1%), and for speech perception in noise (P < 5%). The scores for noise annoyance with BCD1 and BCD2 are not significantly different at the 5%-level. Scores with BCD-P are not significantly different from those with BCD2 (P > 5%).

Device preferences are shown in Figure 6. One patient prefers BCD1, 2 patients have a preference for BCD2, and 7 patients have a strong preference for BCD2.

4 | DISCUSSION

The similarity of aided thresholds for BCD1 and BCD2 point to similar gain characteristics for low-level sounds.

The better performance shown in Figure 3, that is a lower signal-to-noise ratio, with BCD2 relative to BCD1 in the S0N0 condition, that is speech and noise are presented in front of the listener, reflects the combined effects of less signal distortion and more high-frequency gain with BCD2.

Interestingly, scores in the S0N180 condition are similar for BCD1 and BCD2. In this condition, a body-worn device benefits substantially from shielding noise from the rear by the body, the body-shadow effect. In our measurement set-up, this effect for BCD1 amounts to 6.4 dB, the difference between S0N0 and S0N180. A head-worn device like BCD2 does not benefit from the body-shadow effect. However, directional microphone systems generally
provide maximum suppression of sounds from the rear. The suppression by the directional microphones of BCD2 is about equal to the attenuation of rear noises by the body with BCD1. The difference in signal-to-noise ratio for BCD2 in the S0N-90 and the S0N+90 condition is due to an attenuation of the noise coming from the contralateral side of the implant, the head-shadow effect. For the head-worn BCD2, the head-shadow effect amounts to 4.0 dB. There is, of course, no significant head-shadow effect for the body-worn BCD1 (P > 5%).

The head-shadow effect is somewhat smaller with BCD-P than with BCD2 due to its position on the abutment further to the back on the skull, a microphone location effect.

The results with the APHAB and SSQ questionnaires shown in Figure 4A,B illustrate clear differences in signal quality between BCD1 and BCD2. The importance of signal quality is corroborated by essentially identical scores for BCD2 and BCD-P. Scores for the ease of communication and background noise domains of the APHAB and the speech domain of the SSQ are significantly better for BCD2 than for BCD1. Interestingly, despite a 10 dB higher MFO level (for frequencies above 1 kHz) of BCD2 relative to BCD1, scores for the aversiveness for loud sounds domain with the APHAB are essentially equal for BCD1, BCD2, and also for BCD-P. Apparently, the increased MFO level of BCD2 does not have a detrimental effect on the perception of loud sounds.

The scores on visual analogue scales for speech-in-quiet and speech-in-noise shown in Figure 5 are in line with the APHAB scores for the EC and BN domains and the SSQ speech domain. Again, scores for BCD2 and BCD-P are not significantly different (P > 5%).

Data for patients with a profound mixed loss fitted with a super-power sound processor (BCD2) are not significantly different from those for patients with a severe mixed loss and a powerful sound processor (BCD-P).

Finally, Figure 6 shows that 2 of 10 patients have a strong preference and 7 patients have a preference for BCD2 over BCD1. This preference reflects more appropriate signal processing and shaping of maximum power output in BCD2 over BCD1. One patient prefers BCD1 because of its easy-to-use built-in telecoil facility.

Note: when the experiments were finished, Cochlear introduced the Mini Microphone 2+ that features a built-in telecoil and wireless connection to BCD2.

ACKNOWLEDGEMENTS

This study was approved by the ethical committee of the Radboud University Medical Center, Nijmegen, the Netherlands (CMO file: 2015-2149). The measurements were carried out by Herman Kok, Teja Repkes, and Mieki Verbruggen. This study was financially supported by Cochlear.

CONFLICT OF INTEREST

None declared.

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How to cite this article: Bosman AJ, Kruyt IJ, Mylanus EAM, Hol MKS, Snik AFM. On the evaluation of a superpower sound processor for bone-anchored hearing. Clin Otolaryngol. 2018;43:450-455. https://doi.org/10.1111/coa.12989