Bilateral Bone-Anchored Hearing Aids (BAHAs): An Audiometric Evaluation

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Study Rationale and Background

- BAHAs are being used for patients with conductive and mixed hearing loss
- Patients with symmetric hearing loss prefer bilateral amplification with hearing aids
- Patients in the study wearing bilateral BAHAs reported subjectively better hearing with 2 devices (better sound quality and directional hearing), and commonly wore both

- Is there objective hearing improvement with bilateral BAHAs?
  - Based on directional hearing, speech perception in quiet and noise and BMLD (binaural masking difference test)
C300 and Compact BAHAs are directly vibrating bone
Bilateral BAHAs

• Measurements of bone conduction sound transmission > difference in sound transmission from one BAHA to each cochlea is less than 15dB (esp. lower frequencies)

• Are bilateral BAHAs truly improving binaural hearing or this just an effect of greater overall stimulation level through two amplifiers?

• Effect categories:
  > Improved hearing thresholds
  > Directional hearing
  > Binaural hearing
Bilateral BAHAs

- **Directional hearing**: Ability to localize the spatial direction of sound

- **Binaural hearing**: Ability to use binaural cues (use the different sound information at the two cochleae to improve hearing)

- **Head-shadow effect**: Sound presented to poor hearing ear has to pass through the head to get to other side, which attenuates speech intensity
Study population – Table 1

- 12 adult patients with bilateral BAHAs (> 1 year), 11/12 with daily use
- 9/12 with mixed HL, 3/12 with CHL
- 10/12 with symmetric SNHL (< 10 dB difference at 0.5, 1, 2 and 4 kHz)
- 2/12 with asymmetric SNHL (< 20 dB)

**TABLE 1.** Characteristics of the 12 Included Patients.

<table>
<thead>
<tr>
<th>Number</th>
<th>Sex</th>
<th>Age (years)</th>
<th>Type of Baha Left</th>
<th>Type of Baha Right</th>
<th>Abutment Left</th>
<th>Abutment Right</th>
<th>First Fitted Side</th>
<th>Subjective Best Side</th>
<th>Baha Experience</th>
<th>First Side</th>
<th>Second Side</th>
<th>Etiology</th>
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<td>1</td>
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<td>42</td>
<td>Comp</td>
<td>Comp</td>
<td>S</td>
<td>S</td>
<td>L</td>
<td>R</td>
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<td>6.7</td>
<td>55</td>
<td>17</td>
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<td>2</td>
<td>F</td>
<td>68</td>
<td>C300</td>
<td>C300</td>
<td>B</td>
<td>B</td>
<td>R</td>
<td>R</td>
<td>17.5</td>
<td>15.1</td>
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<td>52*</td>
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<td>3</td>
<td>F</td>
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<td>B</td>
<td>B</td>
<td>L</td>
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<td>B</td>
<td>B</td>
<td>R</td>
<td>R</td>
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<td>17.0</td>
<td>10.1</td>
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</table>
Study test setup: Free Soundfield – Figure 1

- 12 speakers, 30° intervals
- Free soundfield tone thresholds were tested from 4 directions
- 3 conditions:
  - unilateral (better) BAHA
  - unilateral BAHA (shadow side)
  - bilateral BAHAs
Study test setup: Directional hearing

- 12 speakers, 30° intervals
- Narrow-band noise at 0.5 or 2 kHz at 65 dB HL for 1 s
- 3 conditions:
  > unilateral (better) BAHA
  > unilateral BAHA (shadow side)
  > bilateral BAHAs
- Repeated x3 from each speaker (total 12 directions)
Study test setup: Speech perception threshold

- Three-word sentences at 0° (3 lists with 10 sentences)
- In quiet and noise (65-80 dB HL)
- Noise was presented from either left or right or all speakers (surrounding noise)
- 2 conditions:
  - unilateral (better) BAHA
  - bilateral BAHAs
- Repeated x2
Study test setup: Binaural Masking Level Difference (BMLD) Test

- Tests true binaural hearing
- Tested with bilateral BAHAs
- Pure tone presented in noise
- 3 conditions:
  - Tone and noise presented equally to both sides
  - Tones out of phase (180°) on both sides, but noise levels the same
  - Noise at both sides out of phase (180°), but tones in phase
- Sound directly supplied to BAHA transducer, no microphone
- 0.25, 0.5 and 1 kHz, at 65 dB HL, x2 repeats
Results: Free Soundfield – Figure 2

- Unilateral vs bilateral BAHA fitting
- Average improvement with bilateral fitting ~2-7 dB
- Greater when presented on shadow side with bilateral fitting: ~5-15 dB, as head-shadow effect is minimized (but: highest SD)
- Great variability, no significance
Results: Directional Hearing – Figure 3

- Patients ability to locate sound source
- Larger circle = more responses, correct responses along diagonal line
Results presented as correct score or whether within 30° of stimulation at 0.5 and 2 kHz.

- Unilateral BAHA sides are similar, and close to chance (8.5% correct, and 25% within 30°)
- Bilateral BAHA increases ability to locate sound correctly (Significance??)
Results: Speech perception threshold

- **Average threshold in quiet:**
  - Unilateral BAHA: 38.7 dB HL
  - Bilateral BAHA: 33.3 dB HL
- **Significant improvement of 5.4 dB (P=.001).**

- **Speech perception in noise:**
  - Noise on better side: 3.1 dB SNR improvement in bilateral BAHAs vs unilateral
  - Noise on shadow side: 1 dB SNR decrease in bilateral BAHAs vs unilateral
  - Surrounding noise: 2.8 dB SNR improvement in bilateral BAHAs vs unilateral

- No significant improvement of speech perception in noise with bilateral BAHAs
Results: Binaural Masking Level Difference (BMLD) – Figure 5

- At 250 Hz, changes for different conditions within 3 dB, (2 patients -18dB to 3 dB, average -5 dB)
- At 0.5 and 1 kHz, threshold changed for 2) and 3) between -10 dB to 10 dB for most patients:
  - 0.5 kHz: 2 dB for 2); -4 dB for 3)
  - 1 kHz: 3 dB for 2); -3 dB for 3)

1) Tone and noise presented equally to both sides
2) Tones out of phase (180°) on both sides, but noise levels the same
3) Noise at both sides out of phase (180°), but tones in phase
Discussion points

• Results overlap with prior studies: Slight, significant improvement in speech perception in quiet, and trend towards improvement in directional hearing and BMLD.

• Different testing setup may explain slightly lower scores for directional hearing

• Speech perception in noise only increased by 2.8 dB> deactivation of one BAHA in directed noise

• Patients with CHL did better than patients with mixed HL> SNHL may be limiting factor to bilateral BAHA benefit