Insert Earphone Depth and the Occlusion Effect

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Twenty individuals were tested to determine the occlusion effect caused by supraaural earphones and by insert earphones with shallow and deep insertion of its foam eartip. The bone-conduction oscillator was placed both on the forehead and the mastoid. It was concluded that using deeply inserted earphones is the most practical way in which to carry out clinical bone-conduction measurements.

Key Words: bone conduction, insert earphone, insertion depth, occlusion effect, supra-aural earphone

The occlusion effect (OE) is the lowering of the intensity required to find bone-conduction (BC) thresholds when an ear is occluded, as opposed to when it is uncovered. The occurrence of the occlusion effect is clinically relevant because it must be considered every time masking is used during testing (e.g., Goldstein & Newman, 1994). Because the interaural attenuation for bone conduction must be considered to be 0 dB, it can rarely be known which cochlea is responding to a BC stimulus unless masking is applied to the ear not under investigation (e.g., Martin & Clark, 2000). Of course, it is not always necessary to be certain which cochlea has responded when that information is not diagnostically important; this is the case when there is no air-bone gap (normal hearing or sensorineural hearing loss) in the test ear. When the non-test ear (NTE) is covered by a supraaural earphone (SAE) or plugged by the foam eartip of an insert earphone (IE), some OE is evident, except for patients with conductive hearing loss (e.g., Dirks, 1994).

The literature on the OE shows that it is inversely related to frequency and is rarely if ever seen at 2000 Hz and above (e.g., Elpern & Naunton, 1963). Occluding the NTE increases the intensity of a BC tone in that ear, making it more likely that it will respond instead of the test ear (Fagelson & Martin, 1994). Failure to make an allowance for the OE by increasing masking intensity guarantees undermasking in many cases (Martin, Butler, & Burns, 1974).

The purpose of this study was to compare forehead and mastoid BC thresholds with both ears unoccluded to those thresholds with the NTE occluded using three different occluding conditions: an SAE, an IE with shallow insertion of the foam eartip in the external auditory canal (EAC), and an IE with deep insertion of the foam eartip in the EAC.

Method

Participants

Participants included 20 women, 20 to 30 years of age, with hearing within normal limits (air-conduction [AC] thresholds 15 dB HL or better at 250-4000 Hz), normal otoscopic examination, and normal tympanogram (peak pressure ± 25 daPa).

Equipment

All testing was done with a GSI 16 audiometer, TDH-39 supraaural earphones mounted in MX-41/AR cushions, a Radioear B-71 BC oscillator, and an ER-3A tubephone as the IE. Normal BC calibration procedures to ANSI (1996) standards were carried out using a B&K type 4930 artificial mastoid connected to a B&K type 2203 sound-level meter with a type 1613 filter set.

Procedure

Unoccluded BC thresholds were obtained at 250, 500, and 1000 Hz with the BC oscillator on the forehead and the mastoid using the ASHA (1978) procedures. During the mastoid testing the occluded ear was contralateral to the oscillator. BC thresholds also were obtained with three different forms of occlusion of one ear: (1) SAE; (2) IE with shallow insertion, that is, the outermost part of the foam eartip even with the tragus (see Figure 1); (3) IE with deep insertion, that is, the outermost part of the foam eartip even with the opening of the EAC (Clark and Roeser, 1988) (see Figure 2). Note that the deep insertion in the present study differed slightly from that used by Clark and Roeser, where the
foam eartip was inserted in the canal until resistance was met, and is illustrated as being slightly deeper than the opening of the EAC.

In condition 1 the SAE was positioned over one ear with the opposite phone placed on the temple. In conditions 2 and 3 the foam eartip of the IE was compressed with the fingertips and initially placed in the canal as far as possible, and then the pinna was pulled up and back to straighten out the EAC so the foam eartip could be gently guided further into the canal until the outermost part of the eartip was even with either the tragus (condition 2) or the opening of the EAC (condition 3). The patients were then asked to open and shut their jaws several times in order to seat the foam eartip.

To control for order effects with respect to BC oscillator placement, the ear that received testing from the mastoid and the occluded ear were counter balanced. The order of the occluding earphones and the order of the frequencies tested were randomized.

Results

The OEs using SAEs were consistent with previous studies showing a decrease as frequency was increased. The greatest effect was observed at 250 Hz (19 dB), followed by 500 Hz (15 dB) and then 1000 Hz (3 dB). Results for forehead and mastoid placement of the BC oscillator were similar. Occlusion effects using an IE with

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Placement</th>
<th>Supra-aural (dB)</th>
<th>Insert Earphone</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Shallow (dB)</td>
<td>Deep (dB)</td>
</tr>
<tr>
<td>250</td>
<td>Forehead</td>
<td>Mean 21</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD 7.9</td>
<td>7.1</td>
</tr>
<tr>
<td></td>
<td>Mastoid</td>
<td>Mean 17</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD 4.3</td>
<td>6.6</td>
</tr>
<tr>
<td>500</td>
<td>Forehead</td>
<td>Mean 18</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD 6.3</td>
<td>6.1</td>
</tr>
<tr>
<td></td>
<td>Mastoid</td>
<td>Mean 13</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD 4.4</td>
<td>4.5</td>
</tr>
<tr>
<td>1000</td>
<td>Forehead</td>
<td>Mean 3</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD 5.2</td>
<td>6.8</td>
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<tr>
<td></td>
<td>Mastoid</td>
<td>Mean 3</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD 5.2</td>
<td>6.0</td>
</tr>
</tbody>
</table>
shallow insertion showed the same frequency/OE relationship (OE = 16 dB at 250 Hz, 12 dB at 500 Hz, and 6 dB at 1000 Hz). The effects on the OE using deep insertion of an IE were interesting but not entirely surprising given the theoretical consideration that the greater the occlusion of the EAC, the smaller the remaining resonating area. Here the OEs were 9 dB at 250 Hz, 7 dB at 500 Hz, and 0 dB at 1000 Hz (see Table 1).

A 2 × 3 × 3 analysis of variance (ANOVA) with repeated measures was performed in order to determine whether significant differences exist for oscillator placement (forehead and mastoid), type of occlusion (SAEs, shallow insertion of an IE, and deep insertion of an IE), and frequency (250, 500, and 1000 Hz). The results of the ANOVA, as shown in Table 2, indicate a significant interaction \((p = .0001)\) between type of occlusion and frequency. There was no significant difference in OE for forehead and mastoid placement.

In order to determine the source of the interaction Scheffé post hoc tests were performed. The interaction is explained by significant differences \((\alpha = 0.05)\) in the OE as a function of frequency with respect to the SAE and the IE shallow insertion conditions. That is, at 500 Hz the OE is significantly less for the IE shallow insertion condition than for the SAE condition; however, at 1000 Hz, the OE is significantly less for the SAE condition than for the IE shallow insertion condition. The results also indicated that the OE in the IE deep insertion condition was significantly less \((\alpha = 0.05)\) than the OE in all other conditions at all frequencies tested.

### Conclusions

The OE does not vary significantly with respect to oscillator placement, but it is significantly less when the NTE is occluded with deeply placed IEs than either shallow-placed IEs or SAEs. The OE is significantly less with shallow insertion of IEs than SAEs at 500 Hz and less with SAEs than with shallow insertion of IEs at 1000 Hz. The OE is not clinically significant at 1000 Hz when deep insertion of IEs is used.

### Clinical Implications

The results of this study lead us to recommend the use of deeply placed IEs for masking during BC testing. In this condition less masking is needed in the NTE because less is required to offset a smaller OE. The use of less masking decreases the probability of overmasking. The OE does not need to be determined at 1000 Hz because it is negligible, saving valuable clinical time.

The following procedure is recommended for routine clinical BC testing with masking:

1. Place the BC oscillator on the preferred site (forehead or mastoid).
2. Find the BC thresholds (unoccluded) at 250 and 500 Hz.
3. Place an insert-masking receiver in the NTE using deep insertion.
4. Remeasure the thresholds at 250 and 500 Hz.
5. Subtract the results of no. 4 from no. 2. This is the OE.
6. Calculate the level of effective masking to be applied to the NTE by adding the OE at 250 and 500 Hz to the AC thresholds at those frequencies.

### References


