The Occlusion Effect
(the bit that makes one's own voice sound boomy)

Cause of the problem
Magnitude of the problem
The mandible or jaw bone
Jaw vibration re Skull vibration

![Graph showing level difference in dB for different subband centre frequencies in Hz for two subjects.](image)
Your turn
Figure 5.20 Axial view of earmolds or shells that produce a very strong occlusion effect (A), and a very weak occlusion effect (B). The mold or shell shown in (C) will produce a weak occlusion effect and will also have minimal leakage of sound from the hearing aid. In each case, the wavy lines show the vibrating anterior wall and the arrow shows the primary direction in which bone conducted sound will travel once it enters the ear canal. The looseness of fit in each diagram has been exaggerated for clarity.
**Figure 5.18** Increase in ear canal SPL (relative to no earmold) for the octave centered on 315 Hz when an aid wearer talks. Ear canal length was measured from the ear canal entrance along the center axis of the ear canal. For this person, the transition from cartilaginous to bony canal, as evidenced by the texture of the impression surface, commenced 9 mm into the canal (on the posterior wall, at the second bend) and completed 16 mm into the canal (on the anterior wall).
Figure 5.19 The mean increase in SPL (relative to no earmold) in the ear canal for 10 subjects, as they talked while wearing earmolds with vents of different sizes.\textsuperscript{1157}
Traditional solutions to the occlusion effect
Solution 1 – deep fitting

Super soft material required!
Solution 2a: Large vent BTE

Relies on feedback cancellation
Vent size and occlusion SPL

Source: 1984 data, in Dillon (2001): Hearing Aids
Solution 2b: Open fitting BTE

Relies on feedback cancellation
Problems with open fittings

• Limited ability to obtain target high frequency gains
• Reduced effectiveness of directional microphones (and future higher directivity direction microphones)
• Reduced effectiveness of adaptive noise suppression
Multi-path propagation

Source
Vent and amplification path transmission

![Graph showing insertion gain vs frequency for different paths: Vent path, Amplified path, and Combined path. The graph displays insertion gain in dB on the y-axis and frequency in Hz on the x-axis. The Combined path shows a peak around 2k Hz, while the Amplified path has a linear increase. The Vent path decreases with frequency.]
Without a vented earmold, what else can we do to solve the problem?
Active occlusion reduction

Jorge Mejia
Occlusion cancelling, and vent cancelling
Electronic Venting

• Create a sound within the ear canal that will cancel the sound generated by the occlusion.

• For perfect cancellation this sound must be equal in magnitude to the occlusion signal but 180 degrees out of phase.

• Perfect cancellation not needed! 10 dB reduction at 300 Hz adequate.
Figure 8.15  Active occlusion reduction system, shown inside an ITC hearing aid, but also able to be implemented as an RITC hearing aid.
Simulations and predicted responses
Occlusion reduction: Mean and Standard Deviation

Note that feedback gain was adjusted for all subjects, filter settings remain the same.
Subjective trials
Subjective trial – 1. Normal hearing

12 subjects enlisted for the trials (normal hearing people).

Why normal hearing subjects?

– They are most susceptible to the occlusion effect.
– Testing the occlusion subsystem, but aid path also present.
– We hope to restore the naturalness of one’s own voice, compared to the open ear. Hence, we need a subjective evaluation from a monaural test.
Conclusions

- Measurements show an average 15 dB reduction of occlusion at the frequency most affected by occlusion.

- Subjective evaluation also indicates a desirable outcome, improving comfort for 12 out of 12 subjects and achieving natural (open-ear) voice quality for 10 out of 12 subjects.
Subjective evaluation 2 – Hearing-impaired

• Methods
  – 24 hearing-impaired participants
  – Two devices were tested.
    • Conventional inside-the-ear (ITEs) hearing aids. Vents used were 1.5 to 3 mm in diameter.
    • The new ITE having the new active vent cancellation feature and a 0.8 mm vent size.
  – Home trials, each devices was tested for at least 2 weeks.
  – Devices were rated before and after home trials
Mild to moderate HL in the high frequencies
Symmetric HL left and right ears
Outcomes: Technology validation

Immediately post fit: overall preference ratings and the right figure shows the mean averages with 95% confidence intervals.

\[ F(1,22) = 0.26, p = 0.62 \].
Outcomes: Technology validation

Device exit questionnaire: Spatial Speech Quality (SSQ) scores, with higher numbers indicating better performance.
Active Occlusion Cancelling Demonstration
Male “eee….”, without, and then with anti-occlusion scheme

Microphone directly inside the completely occluded ear canal
Continuous discourse

Level in volts (digital)

Continuous discourse

\[ \text{Level} = -4.01 \]

\[ \text{Level} = -14.89 \]

Reduction Off \( \rightarrow \) Reduction On
Active Occlusion Cancelling
Disadvantages
Disadvantages of Active Occlusion Cancelling

• (Possibility of instability)
• (Possibility of higher internal noise)
• Two places for wax and moisture to enter the ear canal
Active Occlusion Cancelling Advantages
Advantages of Active Occlusion Cancelling

- Occlusion SPL removed, with no additional leakage out past earshell → higher gains possible
- Vent and leakage inwards transmission also cancelled → Amplified sound path dominates over full amplification bandwidth
  - Directional microphones more effective
  - Adaptive noise suppression more effective → (negative gains)
- Standardization of vent sizes
- Internal microphone can be used for other purposes (REM, self diagnosis, own-voice detection)
- Beneficial for hearing protectors as well
- Consistent time-of-arrival over complete bandwidth → localization, spatial separation (hypothesis)
The end
	hanks for listening