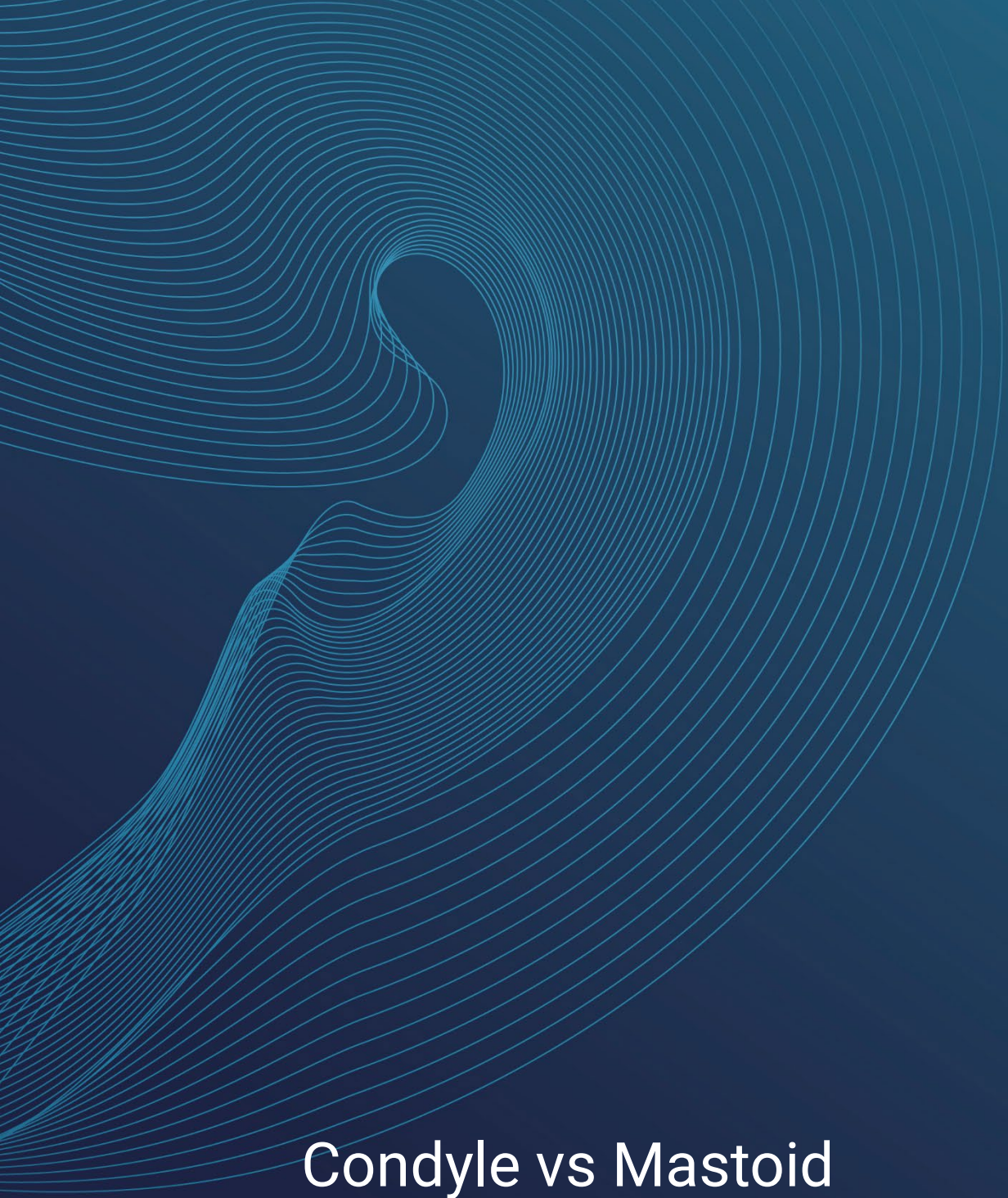


Condyle vs Mastoid

Converging Evidence for Ossiclear System's Two-Site Architecture

soundduct

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1. Abstract

The Mastoid is the historical, standardized reference site for bone-conduction audiometry (ISO 389-3) and the anchor site used by surgically implanted devices such as BAHA (Cochlear) and Ponto (Oticon). Independently, two studies that directly name and test the Condyle in normal-hearing, open-canal subjects[1] rank it among the most sensitive non-invasive stimulation sites measured on the head. In both studies, it ranks ahead of the Mastoid. Sounduct's internal measurements, taken with the ear canal occluded, directly compare the two sites and show a Condyle advantage below roughly 1 kHz that reverses in favor of the Mastoid above that frequency.

[1] Maranda McBride et al., "Bone Conduction Reception: Head Sensitivity Mapping," *Ergonomics* 51, no. 5 (2008): 702–18, https://doi.org/10.1080/00140130701747509; Ivo Dobrev et al., "Influence of Stimulation Position on the Sensitivity for Bone Conduction Hearing Aids without Skin Penetration," *International Journal of Audiology* 55, no. 8 (2016): 439–46, https://doi.org/10.3109/14992027.2016.1172120.

2. Mastoid and Condyle as bone conduction areas

Sound can reach the cochlea through several distinct mechanical pathways. Alongside air conduction, bone conduction and cartilage conduction offer alternative or complementary routes able to bypass a failure of the external or middle ear[2]. The Ossiclear System exploits these pathways at two different anatomical sites: a rear pod on the Mastoid process, and a front pod on the Condyle area (Figure 1).

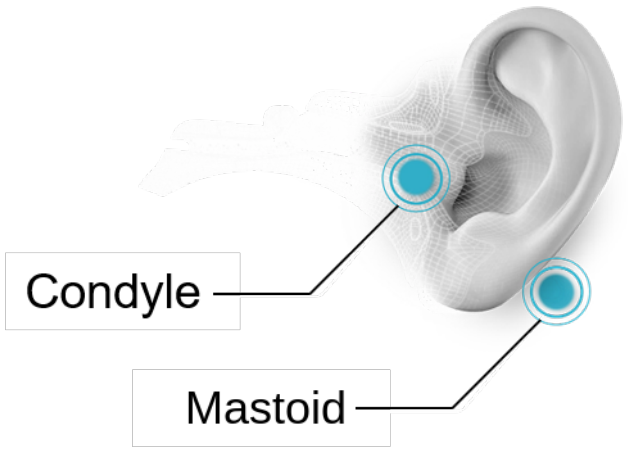


FIGURE 1. OSSICLEAR SYSTEM'S TWO STIMULATION SITES

On the one hand, the Mastoid is the more standardized of Ossiclear System's two sites for hearing aids. It is the reference site for clinical bone-conduction audiometry[3], and it is slightly lower than the site used by surgically anchored bone-conduction hearing aids such as BAHA and Ponto, implanted roughly 55 mm behind the ear-canal opening. Dobrev et al. (2016)[4] further report that the Mastoid sits within a broader region where output is comparatively insensitive to small placement changes, consistent with its reliability in routine clinical use.

On the other hand, Condyle stimulation is more commonly found outside clinical audiology, in publicly available bone-conduction products. For instance, consumer bone-conduction headphones rest on the Condyle area in front of the ear.

This well-known example indicates that placement in the Condyle region is the more commonly adopted approach for non-medical bone-conduction devices.

[2] Hiroshi Hosoi et al., "Cartilage Conduction as the Third Pathway for Sound Transmission," *Auris, Nasus, Larynx* 46, no. 2 (2019): 151–59, https://doi.org/10.1016/j.anl.2019.01.005.
[3] "ISO 389-3:2016," ISO, accessed September 10, 2026, https://www.iso.org/standard/59759.html.
[4] Dobrev et al., "Influence of Stimulation Position on the Sensitivity for Bone Conduction Hearing Aids without Skin Penetration."

3. Relative sensitivity of the Condyle and the Mastoid

Of the two areas, the Condyle is the more sensitive non-invasive site measured in open-canal listeners. Two studies directly name and test the Condyle, alongside the Mastoid, in normal-hearing subjects with an open ear canal (Figure 2 and Figure 3).

First, McBride, Letowski & Tran (2008)[5] tested 11 head locations, including one explicitly labeled “Condyle”. The Condyle ranked the single most sensitive site overall, both in a quiet environment and under 60 dB of background noise. The Mastoid ranked third in quiet (just behind the jaw angle) and second under noise.

Then, Dobrev et al. (2016)[6] independently tested 7 positions around the pinna, combining audiometric thresholds in living subjects with cochlear-promontory vibrometry in cadaver heads. Their position "P2" (superior-anterior to the pinna), stated by the authors to correspond to McBride's "Condyle," produced the lowest bone-conduction thresholds and the largest cochlear-promontory motion of the seven positions tested, ahead of the Mastoid (their "P4").

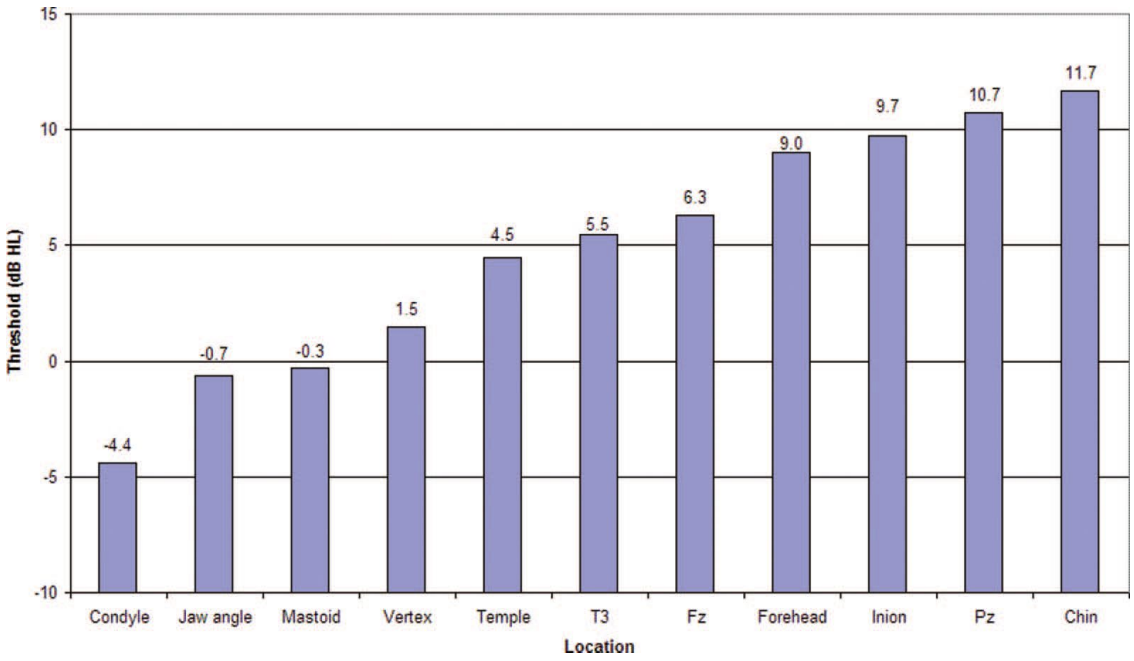


FIGURE 2. MEAN THRESHOLD PER LOCATION ACROSS ALL SIGNALS, EXTRACTED FROM MCBRIDE ET AL. 2008.

[5] McBride et al., “Bone Conduction Reception.”
[6] Dobrev et al., “Influence of Stimulation Position on the Sensitivity for Bone Conduction Hearing Aids without Skin Penetration.”

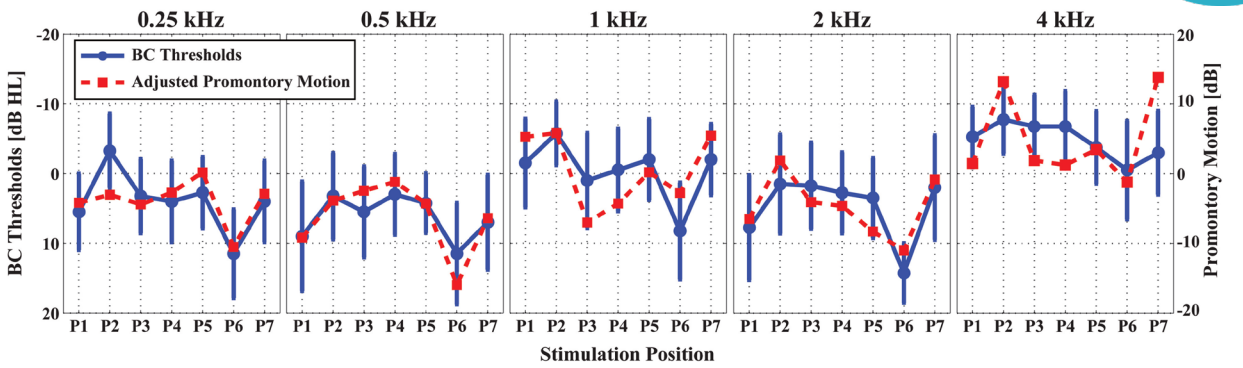


FIGURE 3. BONE CONDUCTION HEARING THRESHOLDS FROM AUDIOMETRIC TESTS (N = 20) IN HUMAN PARTICIPANTS WITH DIFFERENT POSITIONS STIMULATED BY THE B71 BONE VIBRATOR USING A STEEL HEADBAND, IN COMPARISON WITH THE ADJUSTED COCHLEAR PROMONTORY MOTIONS IN CADAVER HEADS WITH DIFFERENT POSITIONS STIMULATED BY THE BAHA TRANSDUCER. THE ADJUSTED COCHLEAR PROMONTORY MOTIONS WERE OBTAINED BY (1) AVERAGING COCHLEAR PROMONTORY MOTIONS SHOWN IN FIGURE 4 ACROSS THREE CADAVER HEADS, AND THEN (2) SHIFTING THE AVERAGED VALUES SUCH THAT THE MEAN COCHLEAR PROMONTORY MOTION ACROSS THE DIFFERENT STIMULATION POSITIONS BECOMES THE SAME AS THE MEAN THRESHOLDS ACROSS THE DIFFERENT STIMULATION POSITIONS, AT EACH STIMULATION FREQUENCY. EXTRACTED FROM DOBREV ET AL. (2016).

This apparent Condyle advantage, however, is not unconditional: it must be understood in light of how each site actually reaches the cochlea. Sugawara, Otsuka & Nakagawa (2021)[7] compared the pinna, the Mastoid, and an area close to the Condyle. Using an earplug-and-water-occlusion technique to isolate the ear-canal-radiated ("osteotympanic") component from the inertial/compressional bone-conduction components, the authors report that the inertial/compressional share of the signal rises with frequency at all three sites, and that this rise is consistently more pronounced at the Mastoid than at the ear-front point. In other words, as frequency increases, the Mastoid signal becomes progressively more dominated by deep bone conduction, while the ear-front point stays comparatively more dependent on the ear-canal-radiated pathway.

This means that the Condyle's superior sensitivity, as measured in McBride[8] and Dobrev's[9] open-canal, normal-hearing subjects, may rest in part on a pathway that requires a patent, functional ear canal to operate. Some patients relevant to bone conduction rehabilitation can present with an abnormal or obstructed ear canal, where this pathway would not be available in the same way. To understand the real-world impact of this dependency, it is therefore useful to carry out measurements directly on patients.

[7] Yusei Sugawara et al., "Estimation of Relationships between Transducer Placements and Peripheral Propagation in Cartilage Conduction," *Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Annual International Conference* 2021 (November 2021): 6755–58, https://doi.org/10.1109/EMBC46164.2021.9629860.
[8] McBride et al., "Bone Conduction Reception."
[9] Dobrev et al., "Influence of Stimulation Position on the Sensitivity for Bone Conduction Hearing Aids without Skin Penetration."

4. Condyle as a BC area for hearing aids

The mechanistic finding from Sugawara et al. (2021)[10], that the Condyle-region signal leans more heavily on the ear-canal-radiated pathway than the Mastoid signal does, raises a legitimate question: could this dependency mean the Condyle loses its advantage once the ear canal is occluded or non-functional? Two further, independently verified sources address this question directly, one mechanically and one perceptually, before the more clinically specific evidence is considered.

Nie et al. (2022)[11] measured the mechanical impedance of the Mastoid and the Condyle in 100 subjects and report that the two sites have different resonance frequencies, 2 kHz for the Mastoid and 0.9 kHz for the Condyle, with an average impedance magnitude difference of 12 dB below 1 kHz, the Condyle being the less stiff, more mobile site over that range. This gives a physical basis for the low-frequency Condyle advantage reported perceptually elsewhere, and for why a handover between the two sites would be expected somewhere in the 0.9–2 kHz region.

Wang et al. (2022)[12] then tested this directly at the level of perception, in normal-hearing listeners with an experimentally occluded ear canal. Eleven participants were tested at the Mastoid, the Condyle, and the temple, using four types of headphones producing different levels of ear-canal occlusion. With an open canal, the Condyle gave the lowest, i.e. best, hearing thresholds of the three positions across nearly the whole tested frequency range. Averaged across the five occlusion conditions tested (open ear plus four headphone types), speech intelligibility at −5 dB SNR in white noise remained significantly higher at the Condyle (59.4% ± 2.1) than at the Mastoid (56.8% ± 2.0, $p = 0.021$), and higher at the Mastoid than at the temple (53.4% ± 2.4, $p = 0.004$). The occlusion effect itself, the additional threshold gain produced by occluding the canal, was numerically larger at the Mastoid (5.9 ± 1.1 dB) than at the Condyle (4.6 ± 1.1 dB), but the difference was not statistically significant ($p = 0.273$); both were significantly larger than at the temple. Occlusion narrows the gap between the two sites slightly on this specific measure, but it does not reverse, or even significantly close, the Condyle's overall advantage on intelligibility. This is direct evidence, on the Condyle itself and now with a supporting mechanical explanation from Nie et al.[13], that the Condyle's advantage over the Mastoid survives ear-canal occlusion.

Wang et al.'s[14] occlusion was produced by headphones over an otherwise normal ear canal, not by the kind of structural pathology, such as atresia or fibrous obstruction, that is part of

[10] Sugawara et al., "Estimation of Relationships between Transducer Placements and Peripheral Propagation in Cartilage Conduction."
[11] Yafei Nie et al., "Measurement and Modeling of the Mechanical Impedance of Human Mastoid and Condyle," *The Journal of the Acoustical Society of America* 151, no. 3 (2022): 1434, https://doi.org/10.1121/10.0009618.
[12] Jie Wang et al., "The Effect of Stimulation Position and Ear Canal Occlusion on Perception of Bone Conducted Sound," *Trends in Hearing* 26 (2022): 23312165221130185, https://doi.org/10.1177/23312165221130185.
[13] Nie et al., "Measurement and Modeling of the Mechanical Impedance of Human Mastoid and Condyle."
[14] Wang et al., "The Effect of Stimulation Position and Ear Canal Occlusion on Perception of Bone Conducted Sound."

Ossiclear System's target population. For that more severe condition, the closest available evidence still comes from a neighboring, though distinct, cartilage-conduction site. Across 53 ears with severe conductive hearing loss and an abnormal ear canal, Nishimura et al. (2021)[15] report that thresholds obtained by stimulating the pinna/concha were significantly better than by stimulating the Mastoid at every frequency below 1,000 Hz, with a gap reaching approximately 20 dB HL between 250 and 1,000 Hz specifically in atretic ears, where the canal was filled with fibrous tissue. However, these are pinna/concha data, not Condyle data, and it does not by itself prove the Condyle behaves the same way in truly pathological ears; it shows that a neighboring cartilage-conduction mechanism does not collapse under the more severe, structural version of the same condition Wang et al.[16] tested experimentally.

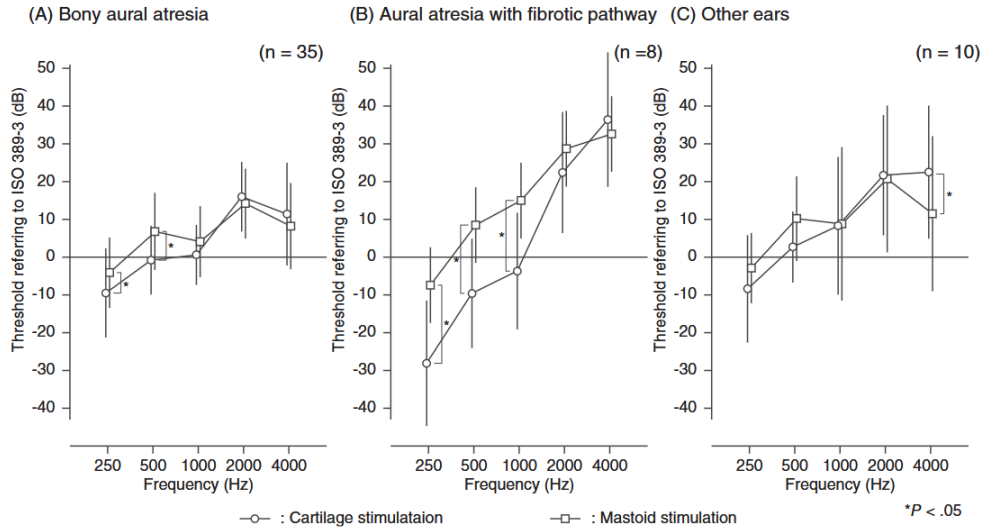


FIGURE 4. THRESHOLD COMPARISONS BETWEEN THE CARTILAGE AND MASTOID STIMULATIONS IN EACH OF THE THREE CONDITIONS OF THE EAR. FOR CONVENTIONAL BONE CONDUCTION, REFERENCE EQUIVALENT THRESHOLD FORCE LEVELS WERE 67, 58, 42.5, 31, AND 35.5 DB RE 1 MN AT 250, 500, 1000, 2000, AND 4000 HZ, RESPECTIVELY. EXTRACTED FROM NISHIMURA ET AL. (2021)[17]

Sounduct's internal measurement sits between these two: it tests the Condyle itself, like Wang et al., but under a simulated occlusion closer in spirit to the pathological-ear question raised by Nishimura. An audiogram taken with the ear canal occluded by a 3M foam earplug, both ears masked, compares the Condyle and the Mastoid directly and shows the Condyle outperforming the Mastoid at low frequency, with a reversal in favor of the Mastoid appearing around 1,000 Hz.

[15] Tadashi Nishimura et al., "Effect of Transducer Placements on Thresholds in Ears with an Abnormal Ear Canal and Severe Conductive Hearing Loss," *Laryngoscope Investigative Otolaryngology* 6, no. 6 (2021): 1429–35, https://doi.org/10.1002/lio2.697.
[16] Wang et al., "The Effect of Stimulation Position and Ear Canal Occlusion on Perception of Bone Conducted Sound."
[17] Tadashi Nishimura et al., "Effect of Transducer Placements on Thresholds in Ears with an Abnormal Ear Canal and Severe Conductive Hearing Loss," *Laryngoscope Investigative Otolaryngology* 6, no. 6 (2021): 1429–35, https://doi.org/10.1002/lio2.697.

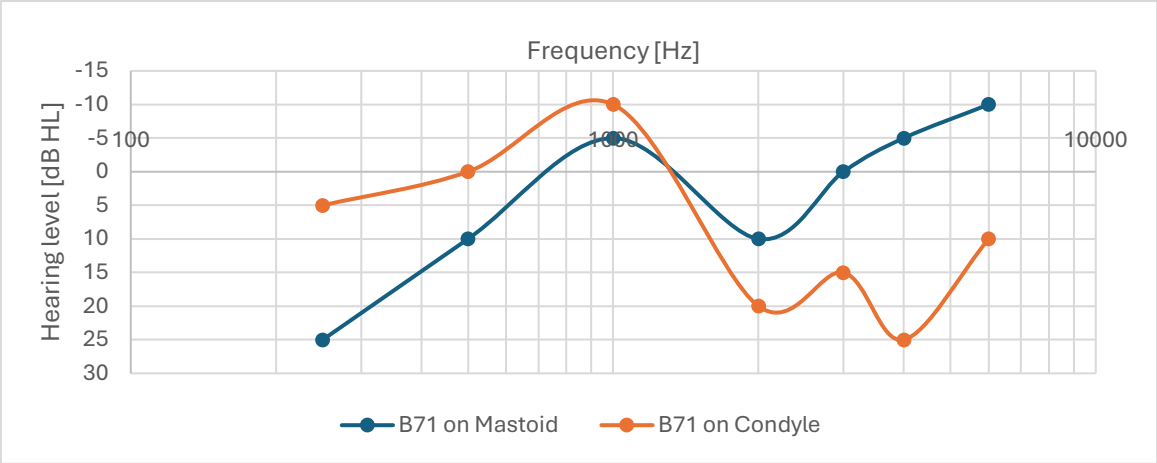


FIGURE 5. INTERNAL AUDIOGRAM WITH BOTH EARS MASKED AND RADIOEAR B71 USED WITH THE OSSICLEAR SYSTEM ADHESIVE PAD.

This is the same low-frequency, Condyle-favoring pattern found by Wang et al. under headphone occlusion and by Nishimura et al. under pathological occlusion, and it lands within the exact 0.9–2 kHz handover window that Nie et al.'s impedance measurements predict.

Taken together, four independent lines of evidence now converge: a mechanical impedance measurement explains why the Condyle should be favored below roughly 1 kHz and predicts where the handover to the Mastoid should occur[18]; a controlled perceptual experiment directly on the Condyle confirms its advantage over the Mastoid survives ear-canal occlusion in normal ears[19]; clinical data on a neighboring cartilage site in patients with real, structural conductive pathology show that the same mechanism does not collapse under a blocked canal[20]; and Sounduct's internal measurement reproduces the identical pattern directly on the Condyle, in the frequency region the mechanical data predicts. No single result here covers every condition Ossiclear System will encounter in the clinic, and the internal measurement remains a single, unreplicated data point, but the case for the Condyle now rests on converging mechanical and perceptual evidence rather than analogy alone. Work is ongoing to add further measurement points and to obtain full-text confirmation of the remaining inherited references.

[18] Nie et al., "Measurement and Modeling of the Mechanical Impedance of Human Mastoid and Condyle."
[19] Wang et al., "The Effect of Stimulation Position and Ear Canal Occlusion on Perception of Bone Conducted Sound."
[20] Nishimura et al., "Effect of Transducer Placements on Thresholds in Ears with an Abnormal Ear Canal and Severe Conductive Hearing Loss."

5. Conclusion

Ossiclear System's two-pod architecture rests on two anatomically and mechanically distinct sites that the literature treats very differently, and that is the point: the Mastoid is the standardized, best-characterized clinical reference, used by surgically anchored devices and largely insensitive to small placement shifts, while the Condyle is the more sensitive of the two in open-canal listeners and, as now shown by four independent methodologies (mechanical impedance, cochlear-promontory vibrometry, and perceptual thresholds and speech intelligibility under both open and occluded conditions), keeps that advantage below roughly 1 kHz even when the ear canal is occluded. Clinical data on a neighboring cartilage site in patients with real conductive pathology, and Sounduct's internal measurement directly on the Condyle, both point the same way for the more severe, pathological version of that same condition. None of this is presented as definitive for every patient Ossiclear System will treat, and some of it, notably the internal measurement and the pinna/concha analogy, remains preliminary or indirect. But taken together, the evidence supports combining the two sites rather than relying on either alone: a well-established Mastoid pathway paired with a Condyle pathway whose low-frequency advantage is no longer just plausible, but measured, mechanically explained, and now converging across several independent sources.