Case Report

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A multimodal fitting approach for the treatment of hearing loss

Abstract

We attempted a multimodal fitting approach on a 22-year-old female patient with profound sensorineural hearing loss (SNHL) in the right ear and moderate-to-profound SNHL in the left ear since she was a child (Prelingual). She has been wearing a cochlear implant on her right ear with the Kanso one sound processor (Nucleus® Sound Processor from Cochlear Ltd) and a Resound behind the ear (BTE) hearing aid on her left ear (Bimodal fitting). We used a combination of electrical-acoustic stimulation plus (EAS-P), vibration-acoustic stimulation (VAS), and vibration-electrical stimulation (VES) to investigate whether the patient's speech recognition in a noisy environment improves with our multimodal approach compared to the bimodal fitting approach. We used MedRx Audiometer for our evaluations and the calibration was done before our assessments.

Keywords: sensorineural hearing loss, bone conduction hearing aids, bone anchored hearing aid, piezoelectric stimulation, mixed hearing loss, single side deafness, cochlear implant

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Introduction

Many patients encounter poor speech recognition in noisy environments such as restaurants, meetings, church, etc., despite wearing hearing aids and/or cochlear implants. The physiology of the auditory system is very complex and both peripheral and central systems are involved in speech recognition.[1] The auditory system is a bottom-up/top-down stimulation system and all the treatment options such as hearing aids, cochlear implants, gene therapy and stem cell therapies target the bottom-up stimulation and not the top-down processing system although improving the bottom-up stimulation may indirectly promote the function of the top-down auditory system.[2] A bottom-up/top-down stimulation system is needed for improving speech recognition in a noisy environment; for instance, a cochlear implant combined with another electrical prosthesis which simultaneously can stimulate the medial olivary complex and/ or primary auditory cortex (depending on the site of lesions) or a cochlear implant and a brain-computer interface simultaneously. Despite the ongoing research in this aspect, it is not clinically applicable now. Our approach in this study is also a bottom-up stimulation; however, it is a multimodal approach.[3]

Case report

At the first session of our evaluation, we performed pure tone audiometry (PTA), Speech reception threshold (SRT), most comfortable loudness (MCL), and word recognition score (WRS) tests without the patient's bimodal fitting (Unaided). Subsequently, we performed the SRT, MCL, and WRS with the patient's bimodal fitting (Aided). The Quick Speech in Noise (QuickSIN) test (unaided and aided) with the patient's bimodal fitting was also performed. We also used two Ponto 3 super power Oticon bone conduction hearing aids (BCHA) with the test bands and electronically adjusted them for the patient, without her hearing aid and cochlear implant. We obtained the impression from the patient's right ear canal to design an ear mold and to attempt the electrical acoustic stimulation plus (EAS-P) modality. We received the ear mold from the manufacturer after two weeks and we scheduled the second and last session of our evaluation with the patient. In the second session of our evaluation, we performed the QuickSIN test with different modalities. For the vibration-electrical stimulation (VES) modality, we used Ponto[3] Oticon super power BCHA with the test band (vibration stimuli) and Kanso one sound processor cochlear implant (Electrical stimuli) simultaneously on the right ear. For the EAS-P modality, we used a Kanso one cochlear implant (Electrical stimuli) and Phonak Naida Paradise 90 UP (acoustic stimuli) simultaneously on the right ear. For the VAS modality, we used Ponto[3] super power BCHA with the test band (vibration stimuli) and a Resound BTE hearing aid (acoustic stimuli) simultaneously on the left ear. We performed the QuickSIN test with the bimodal fitting first and subsequently, we performed the QuickSIN test with the different modalities mentioned above. We compared the result of different modalities with that of bimodal fitting only. All modalities used in our study showed significant improvement in speech recognition in noise, compared to the only bimodal fitting (Table 1).

Table 1 Quick speech in noise test results in five different modalities

Modalities	Quick SIN Right ear	Quick SIN Left ear	Quick SIN Both ears
Bimodal fitting [Right ear CI and left ear BTE hearing aid]	20.5 dB	21.5 dB	10.5 dB
Right ear: VES (BCHA+CI). Left ear : BTE Hearing aid only	11.5 dB	NA	9.5 dB
Right ear: VES (BCHA+CI). Left ear: VAS (BCHA+ BTE hearing aid)	7.5 dB	7.5 dB	4.5 dB
Right ear: EAS-P (CI+BTE hearing aid) Left ear: BTE Hearing aid only	8.5 dB	NA	6.5 dB
Right Ear: EAS-P (CI+BTE hearing aid) Left EAR: VAS (BCHA + BTE Hearing Aid)	NA	12.5 dB	8.5 dB

Discussion

Implantable BCHAs such as bone anchored hearing aid (BAHA), piezoelectric stimulation, Bonebridge, and non-implantable BCHAs such as Adhear are mostly used for the treatment of conductive or mixed hearing loss. This includes patients who suffer from otosclerosis, ossicular chain discontinuity, tympanosclerosis, aural atresia, or patients with chronic otitis media who cannot use traditional hearing aids due to otorrhea and/or patients who suffer from single-sided deafness (SSD). BCHAs are also useful for the treatment of hearing loss in some syndromic diseases such as Treacher–Collins Syndrome. The implantable BCHAs are better than non-implantable ones for better and more direct stimulation. One of the main disadvantages of non-implantable BCHAs compared to implantable options is attenuation in high frequencies.[4,5]

Air conduction hearing aids include behind-the-ear (BTE) aids with occluded or non-occluded ear mold(s) or open-fitting BTE (Thin-Tube). In-the-ear hearing aids include completely in the canal (CIC), mini in the canal (MIC), in the canal (ITC), shell, and invisible in the canal (IIC). Receiver in the canal (RIC) hearing aids with open fitting or ear mold(s) are all used for the treatment of different types and degrees of hearing loss such as sensorineural, conductive, and/or mixed hearing loss.[6–8]

The cochlear implant is a prosthesis that electrically bypasses the cochlea and transmits the signals to the brain and is mainly used for the treatment of patients with moderate-to-profound hearing loss with poor word recognition scores who cannot benefit from conventional hearing aids. Moreover, it is useful for the treatment of patients with single-sided deafness or SSD.[9]

Electrical-acoustic stimulation (EAS) or a hybrid cochlear implant is a combination of a hearing aid and a cochlear implant. The hearing aid component amplifies the low frequencies and the cochlear implant component emphasizes the high frequencies with electrical stimulation. EAS is mainly useful for patients with better hearing in low frequencies and poor hearing in high frequencies. Several studies substantiate the advantage of EAS compared to the traditional cochlear implant.[10]

Electrical-acoustic stimulation Plus (EAS-P) includes two separate prostheses. One BTE hearing aid and one cochlear implant are simultaneously used in one ear to mitigate unilateral hearing loss or SSD. Similarly, two BTE hearing aids and cochlear implants are used on both ears for patients with bilateral profound hearing loss (Figure 1), (the patient signed the consent form regarding publishing this image) In contrast, the EAS is a single prosthesis, which includes the combination of a hearing aid attached to the cochlear Implant.[11]

Figure 1 Electrical-acoustic stimulation plus. The Kanso one sound processor cochlear implant and the Phonak Naida Paradise 90 UP in one ear simultaneously.

EAS-P can only be used as an off-the-ear cochlear implant sound processor since a behind-the-ear cochlear implant sound processor and BTE hearing aid cannot be worn simultaneously. We used a Phonak Naida Paradise 90 UP with the occluded ear mold for the acoustic stimulation and Kanso one cochlear implant sound processor for the electrical stimulation.[11]

The Phonak Naida Paradise 90 UP and the Kanso cochlear implant sound processor have two microphones each. Consequently, the patient in our study could benefit from having four microphones in one ear. Studies show that adding microphones to the hearing aid can boost speech recognition in noise. For instance, the microphone-and-receiver-in-ear hearing aid is a RIC hearing aid with an additional microphone inside the receiver.[12,13]

In EAS-P the mapping of the cochlear implant and the fitting of the hearing aid must be performed separately; however, we believe that the two devices could be matched together.

Vibration-acoustic stimulation (VAS) and vibration-electrical stimulation (VES) are the other two modalities used in this study. VAS is a combination of one bone and one air conduction hearing aid, placed simultaneously in one ear and/or two air and two BCHAs placed simultaneously on both ears for patients who suffer from bilateral hearing loss (Figure 2). The bone and air conduction hearing aids are two separate devices that should be adjusted differently but can be equalized together.[14]

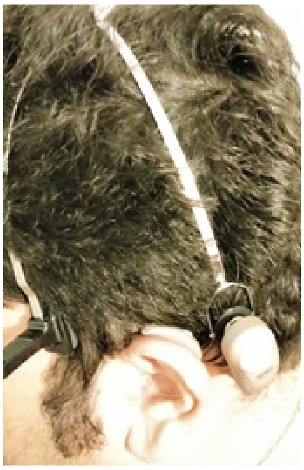

Figure 2 Vibration-acoustic stimulation. Receiver in canal hearing aid and bone conduction hearing aid simultaneously.

VES includes a cochlear implant and BCHA simultaneously in one ear and/or two cochlear implants and two BCHAs at the same time in both ears. As in previous modalities, the fitting of BCHAs and the mapping of the cochlear implant must be performed separately.[15]

In the first session of our evaluations, we performed the PTA, SRT, MCL, WRS, and QuickSIN tests through the headphones (unaided). Subsequently, we performed the SRT, MCL, WRS and QuickSIN tests with the patient's bimodal fitting on (aided) for the right and the left ear and both ears simultaneously through the speakers (Free- Field mode). Quick SIN test is a fast and effective test for evaluating speech recognition in noise.

In unaided evaluations, the patient did not show any response in PTA, SRT, MCL, and WRS on the right ear while masking the left ear. On the left ear, the unaided SRT, MCL and WRS were 70 dB, 95 dB and 42%, respectively (Figure 3).

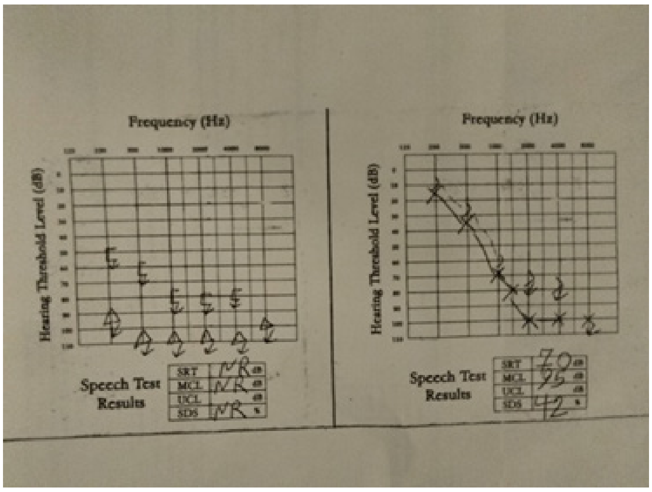

Figure 3 In unaided evaluations 70 dB, 95 dB and 42% respectively

In aided evaluations (bimodal fitting) through the free-field mode the SRT of the left ear changed from 70 dB unaided to 45 dB aided and the WRS of the left ear changed from 42% unaided to 96% aided. On the right ear, the SRT changed from no response unaided to 40 dB aided, MCL changed from no response unaided to 80 dB aided, and the WRS changed from no response unaided to 94% aided. The aided MCL and WRS of both ears (both speakers) were 80 dB and 90%, respectively.

We performed the QuickSIN test for aided (bimodal fitting) through the free-field mode since the patient suffered from severe-to-profound hearing loss in both ears. We used 100 dB as the presentation level for the QuickSIN test. The Quick SIN test results of the right ear, left ear and both ears (both speakers) were 20.5 dB, 21.5 dB and 10.5 dB, respectively.

We obtained the impression of the patient's right ear canal for the EAS-P modality and completed the first session of our evaluations. After two weeks, we received the ear mold and scheduled the second and final evaluations with the patient.

In the final evaluations, we attempted different modalities.

First modality: VES right ear BTE hearing aid left ear

We attempted VES on the right ear using the Kanso one cochlear implant and a Ponto[3] superpower BCHA with the test band simultaneously on the right ear and the Resound BTE hearing aid on the left ear. Next, we performed the QuickSIN test aided through the free-field mode with this modality. The results of the QuickSIN test for the right ear and both ears (both speakers) were 11.5 dB and 9.5dB, respectively.

Second modality: VES right ear and VAS left ear

We simultaneously used a Ponto[3] superpower BCHA with the test band and the Kanso one cochlear implant on the right ear (VES) and simultaneously used a Ponto[3] Superpower BCHA with the test band and Resound BTE hearing aid on the left ear (VAS). Two BCHAs on both ears and one cochlear implant on the right ear and a BTE hearing aid on the left ear (total 4 prostheses on both ears simultaneously). Subsequently, we performed the QuickSIN test with this modality in free-fielded mode. The QuickSIN of the right and the left ear was 7.5 dB and that of both ears was 4.5 dB.

Third modality: EAS-P right ear and Resound BTE left ear

We used the Kanso one cochlear implant simultaneously with the Phonak Naida Paradise 90 UP on the right ear (EAS-P) and the Resound BTE on the left ear. The patient complained of the quality of sound with the EAS-P on the right ear. Since the patient reported distortion and loudness, we decreased the gain in almost all frequencies of the acoustic stimulation (Phonak Naida Paradise 90 UP) which were more in high frequencies and less in low frequencies. Subsequently, the patient reported better quality of sound with EAS-P stimulation. Next, we performed the QuickSIN test with this modality in free-field mode and the result was 8.5 dB for the right ear and 6.5 dB for both ears.

Fourth modality: EAS-P right ear and VAS left ear

We tried the EAS-P stimulation on the right ear (CI+BTE hearing aid) and VAS (Bone + BTE Hearing Aid) on the left ear (a total of four prostheses on both ears). The Phonak Naida Paradise 90 UP and the Kanso one cochlear implant at the same time on the right ear and a Ponto[3] Superpower BCHA with the test band and a Resound BTE hearing aid simultaneously on the left ear. Next, we performed the QuickSIN test with this modality and the result was 12.5 dB for the left ear and 8.5 dB for both ears. The result of our fourth modality was unsatisfactory compared to other modalities. The results could be attributed to the fact that the patient was exhausted during the evaluation of the last modality, affecting the results to some extent.

Our case study indicated that a multimodal fitting approach can improve speech recognition in noise, compared to the bimodal fitting approach.

Conclusion

In our case study a combination of VES and VAS showed a better outcome compared to other modalities with respect to better speech recognition in noise, sound quality and comfort. Probably, this could be due to the application of multi microphones and better stimulation of the cochlea and eventually better stimulation of the brain. Further studies are required in a larger population including patients with bilateral profound hearing loss.

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Conflicts of interest

No conflicts of interest.

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