Critical Review: Is there any evidence of directional microphone benefit in open-canal hearing aid fitting?

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This critical review examines the benefit of directional microphone in improving speech intelligibility in the presence of noise in open-canal hearing aid fitting. Study design for all studies included in this critical review is single group (pre-posttest) with repeated measures. Overall, research suggests that a patient fitted an open-canal hearing aid would require directional microphone in order to perform significantly better than unaided or aided with omnidirectional microphone for listening in noisy environments.

Introduction

The number of patients with high frequency hearing loss due to presbycusis, ototoxicity, noise exposure or combination of these factors is expected to increase globally. Recently, open-canal hearing aid technology has focused on addressing patients with these types of hearing loss (Fabry, 2006).

Listening in noise seems to be the most difficult situation for the individuals with hearing impairment. Typically, hearing instruments improve the audibility of desired sound and makes unwanted sounds louder. This adds up problem for the impaired cochlea. Individuals with sensorineural hearing loss require a higher signal-to-noise ratio (SNR) for speech intelligibility than normal hearing listeners. In addition, the greater the degree of hearing loss, the higher the SNR required for speech intelligibility. Directional microphone is one of the approaches to increase SNR for speech intelligibility in the presence of background noise (Ricketts, 2001).

One question about open-canal fittings is whether or not they can provide directional microphone benefit. Open fittings are the most effective method of decreasing the occlusion effect by allowing an escape of built-up sound pressure in the low frequencies through the increased vent size. However, some concern has been raised about the impact of increasing the vent size on directionality. It has been suggested that the larger vent will compromise the benefits of directional microphones. In a directional microphone, basically sounds from the rear and the side are attenuated in favorite to sounds from the front. The concern is that the large vent will allows low-frequency sound from the rear to pass through the vent without attenuation; thus the directional benefit will be reduced (Flynn, 2004). Therefore, it is essential that research investigates the degree of directional benefit in open-canal hearing aids.

Whether or not the directivity is realized by the hearing aid users depends on many factors, including the “openness” of the ear canal (the larger the vent, the more directivity attenuation in the low frequencies), the lack of low frequency gain therefore limiting low-frequency directivity, and the amount of high-frequency gain and directionality achieved (Klemp and Dhar, 2008). The fact that directional microphones and venting both impact low frequency gain has led many clinicians to conclude that directional microphone benefit for patients with open-canal hearing aids with high frequency hearing loss is negligible. Open-canal fittings often provide a minimal amount of low frequency gain; therefore, it is often difficult to determine the directivity of the microphone. Flynn (2004) indicated that different directional microphones have different frequency responses due to differences in phase matching. An omnidirectional microphone picks up the sound equally from all directions. The microphone though becomes more and more directional the higher the frequency; whereas, directional microphones seen in a number of variations (i.e. cardioid, supercardioid, and hypercardioid) differ in their rejection of sound from sides and rear. Equal sensitivity is shown for both omnidirectional and directional modes in the lower frequencies; however, there is considerable advantage of directionality in higher frequencies. Several manufacturers have enhanced the high-frequency directivity by moving the microphone ports closer together. Since low-frequency signals sampled at the two microphone ports will be more similar in phase than high-frequency signals, a reduction in output for low-frequencies will occur (low frequency roll-off). Closer microphone spacing causes more low frequency roll-off, consequently improves high-frequency directionality, which is critical for open-canal fittings for high-frequency hearing losses (Bentler, Wu, & Jeon, 2006).

Objectives

The primary objective of this review is to critically evaluate existing literature examining the benefit of directional microphone in improving speech intelligibility in the presence of noise in open-canal hearing aids. Literature including comparisons across unaided and aided conditions as well as in different listening situations (i.e., with and without noise) were assessed to determine clinical implications for using directional microphones in open-canal fittings.

Methods

Search Strategy

Computerized databases, including MEDLINE-OVID, CINAHL, SCOPUS, PubMed, were searched using the following strategy:
((open-canal hearing aid) OR (open-fit hearing aid) OR (open hearing aid) AND (directional microphone) OR (directionality))

The search was limited to articles written in English. No other limits were used.

Selection Criteria

Studies included in this critical review examined the benefit of directional microphones in open-canal fittings in relation to speech understanding in noise and/or compared to unaided listening. No limits were set on the demographics (age, gender, culture, race, or socioeconomic status) of research participants or outcome measures.

Data Collection

Result of the literature search yielded the following types of articles congruent with the aforementioned selection criteria: Single group studies with a pre-posttest design. Each of the studies provided a grade III level of evidence (Dollaghan, 2007).

Results

Pre-Posttest Study # 1: Efficacy of an open-fitting hearing aid

Kuk et al. (2005) evaluated differences in performance between unaided and aided performance (omnidirectional and directional) with noise reduction on/off were measured using an open-canal hearing aid. Eight adult subjects with a high frequency sensorineural hearing loss above 1 KHz participated in the study. All were fitted with binaural Widex Diva élan hearing aids with the ear set. Four were experienced hearing aid wearers. The default settings, as prescribed by the manufacturer, were used and no adjustment was made on the hearing aids. Subjects wore the hearing aids for at least 1 week before any testing began and returned for a retest after a week.

The Hearing in Noise Test (HINT) was used to evaluate the participants' ability to recognize speech in noise and to provide an indication of the directional benefit through an individual performance on the given task. A SNR can be calculated from HINT test and this test then provided a decibel difference indication of the directional microphone benefit.

In this study, speech materials were presented from the front speaker, and the noise was presented from three loudspeakers placed at 90°, 180°, and 270°. The noise was presented at 75 dB SPL continuously and the speech level was recorded when 50% correct identification was reached. During the speech-in-noise testing, four different hearing aid settings considered were combination of noise reduction (on & off) and microphone modes (omnidirectional and adaptive directional[1]). The sequence of noise reduction x microphone setting was counterbalanced across subjects. Performance in the unaided condition was evaluated during last visit. This study conducted a directional benefit of 1.8 dB with noise reduction (NR) off or on and a directional benefit of 2.6 dB with NR on and in adaptive mode relative to unaided. Repeated measures analysis of variance (ANOVA) showed that the effect of microphone and of the noise reduction was statistically significant ($F(1, 7) = 16.06$ for microphone and 7.75 for noise reduction, $P < 0.05$).

Kuk et al. (2005) utilized a valid experimental design in this study. Sufficient support for the benefit of directional microphone and noise reduction algorithm was provided in this study. However, only a small number of participants were recruited to participate. In addition, the level of noise presented during the HINT test was quite high (75 dB SPL) compared to other studies. Moreover, experimenter bias may have occurred considering that the author was employed by the manufacturer for which he was doing product research for.

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[1] Adaptive directional microphone has a high in-situ directivity index especially in the low frequencies. In this design maximum directivity index is in high frequencies.

Pre-Posttest Study # 2: Unaided and Aided Performance with a Directional Open-Fit Hearing Aid

The study conducted by Valente and Mispagel (2008) was aimed at measuring differences in performance between unaided and aided performance (omnidirectional and directional) by using an open-canal hearing aid (Vivatone Dual D44 from Vivatone Hearing System, LLC.). These differences were assessed by measuring reception thresholds for sentences (RTS in dB) using HINT test. Twenty-six adults (18 males; 8 females; mean age= 65.6 years; sd= 11.7 years) with no previous amplification experience were selected. Audiometric results indicated normal hearing at 250-500 Hz followed by slight to moderate-severe bilateral symmetrical sensorineural hearing loss at 1000-8000 Hz. None of the participants had conductive components. The directional microphone of the hearing aid has three fixed polar patterns (cardioid, hypercardioid, and bidirectional). Hypercardioid design was chosen for this research because hypercardioid design has the best activity index when sounds come from different angles.

The experimental hearing aid was initially fitted using the manufacturer's default program "First-Fit" algorithm. The participants returned after four weeks for measuring sentence recognition in noise by HINT test. HINT RTS (in dB) were obtained for three listening conditions (unaided, omnidirectional, and directional). HINT sentences presented at 0° with R-Space™ restaurant noise held constant at 65 dBA and presented via eight loudspeaker set 45° apart. These authors have chosen different testing set-up (8 loudspeaker sound-field systems) which has been introduced recently by Revit et al. in order to get realistic microphone performance in the laboratory.

The major findings of the study revealed a directional benefit of 1.9 dB relative to omnidirectional performance ($p < 0.0001$), and a directional benefit of 1.7 dB relative to unaided performance ($p < 0.0001$). In addition, omnidirectional performance (2.8 dB) was statistically the same as unaided performance (2.4 dB), ($p < 0.297$). Therefore, the presence of an omnidirectional microphone in an open-fit hearing aid may provide a level of performance that is the same as unaided in the presence of noise. These results were in agreement with Kuk et al. (2005) in that neither study demonstrated significant differences between unaided and aided omnidirectional condition. Additionally, directional benefit measured in both studies was very similar.

Valente and Mispagel (2008) utilized a valid experimental design in this research study. They reported statistically significant directional microphone benefit in noisy environment in open-canal fitting. However, the participant recruitment procedure was not discussed; patient selection bias may have occurred by offering the option to purchase the experimental hearing aids at a 50% discount at the end of the study or receive compensation of $200.

Pre-Posttest Study # 3: Speech Perception in Noise Using Directional Microphone in Open-canal Hearing Aids

Klempt and Dhar (2008) compared directional performance with both unaided and omnidirectional conditions by measuring the performance of the group using two commercially available open-canal hearing aids (Phonak mini Valeo 101 AZ & Widex Diva élan SD-9Me). Sixteen participants with a bilateral sloping sensorineural hearing loss and no previous hearing aid experience were recruited.

Speech perception in the presence of background noise was evaluated in the participants under unaided, omni, directional with/out digital noise reduction by using the HINT. The sentences were presented from a speaker at 0° azimuth, and 3 channels of uncorrelated noise were presented from matched speakers at 90°, 180°, and 270° azimuth. The speech-shaped noise was constantly at 65 dBA. HINT performance was compared across hearing aids. HINT benefit for the directional microphone, digital noise reduction, and both conditions were compared independently with reference to the unaided and omni conditions using independent general linear models with repeated measures. Individual hearing aids and the conditions within each hearing aid were the factors used in the analysis.

Results suggested a mean difference of 2.26 dB between the directional and unaided condition and a mean difference of 3.32 dB between the directional and omni conditions which is statistically significant ($P < 0.0001$). The research study conducted by Klempt and Dhar (2008) utilized a valid experimental design with no experimenter bias. However, the study did not just focus on directional performance.

Discussion

The results of the aforementioned studies validate directional microphone benefit in open-canal hearing instruments in noisy environments. However, in study

#1 and #3, the directional microphone benefit is evaluated with or without noise reduction algorithm. Through critical analysis of the results of all three studies, it can be indicated that directional microphones with or without noise reduction technology indeed provide an advantage over omnidirectional microphones or unaided performance in open-canal fittings. Although the aforementioned studies indicated that listeners fit with directional open-canal hearing aids obtain better speech recognition in laboratory settings, further research is needed to determine the extent to which that benefit can be generalized to real-world situations.

It should be noted that open-canal hearing aid users do not need amplification in low frequencies and consequently low-frequency directivity is not available for this hearing impaired population. Findings suggest that directional benefit is smaller in open-canal hearing aids as compared to traditional occluded fitting. Nordrum et al, (2006) has reported a directional advantage of 3.5 dB over omnidirectional conditions using closed-canal devices. Klemp and Dhar (2008) reported a smaller and statistically nonsignificant benefit of 3.32 dB using a similar comparison.

Conclusion

Outcomes from the studies explored in this critical review reveal significant directional microphone benefit with or without digital noise reduction algorithm compared to omnidirectional or unaided conditions in open-canal hearing instrument fittings. Therefore, the directional signal processing should not be prevented in open-canal instruments for listening in noisy environments.

Clinical implications

Given the assembled research materials, there is significant evidence supporting the benefit of directionality in open fit hearing aids. Patients meeting the selection criteria (i.e. fitting range of the hearing instrument) will most likely experience greater benefit from an open-canal hearing aid with active directional microphones. Further studies need to include how much directional microphone benefit is needed for the hearing aid users in order to notice the difference between unaided, omnidirectional, or directional performance. Clinicians play an important role in this field. They involved in prescription of hearing instruments and their associated technologies, as well as education and counseling with regards to the expected benefit of these technologies.

Clinicians need to attempt to provide appropriate evidence-based hearing instrument prescription. The cost effectiveness of such technologies should be clearly shared with the clients. Clinicians should consider the directional microphone benefit in open-canal hearing aid fittings to increase speech intelligibility in noise. As clinicians, we must be informed of the efficacy of these technologies and update our knowledge about them.

Also, clinicians are the client's link with hearing instrument manufacturer and the researchers. It is the clinician responsibility to provide the client with unbiased and educated information about the newest technologies. Clients should be clearly informed that the directional microphone can offer better speech understanding in noise if the signal source is located in front and the signal source is relatively near. On one hand, counseling is needed surrounding the expected benefit. On the other hand, clients' education on the effective use of the technology is essential. Clients would benefit from the directional microphone technology more if they know how and when to implement it.

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