ISSN:2395-1079

Available online at http://www.gjms.co.in/index.php/sajms

South Asia Journal of Multidisciplinary Studies SAJMS June 2017, Vol. 3, No 5

UGC 49956-910

PERFORMANCE OF INDIVIDUALS WITH SLOPING SENSORINEURAL HEARING LOSS WITH THREE HEARING AID FITTING STRATEGIES

Reuben J Prabhu
Junior Research Fellow All India Institute of Speech & Hearing, Mysuru, Karnataka, India

P Manjula
Professor of Audiology All India Institute of Speech & Hearing, Mysuru, Karnataka, India

Abstract

Background Hearing aid prescription and acceptance in individuals with sloping sensorineural hearing loss (SNHL) has been a challenge to audiologists and patients alike. There is a dearth of studies on the efficacy of different amplification strategies such as conventional frequency amplification (CFA), frequency compression amplification (FCA) and receiver in the canal (RIC) in the same group of individuals.

Aim To compare the performance with three amplification strategies in individuals with sloping sensorineural hearing loss.

Method 45 ears of participants with sloping sensorineural hearing loss were tested in three aided conditions, i.e., CFA, FCA, and RIC using aided thresholds for warble tones, speech identification scores (SIS) for high frequency words, and signal-to-noise ratio-50 (SNR-50).

Results:

Friedman's test indicated that there was a significant difference in aided thresholds from 0.5 kHz to 6 kHz between CFA, FCA, and RIC strategies. . The Wilcoxon signed ranks test between these three strategies on the aided thresholds revealed that there was a significant difference between each strategy. Further, speech identification task in all the three fitting strategies resulted in similar SIS using high frequency words. The conventional frequency and RIC strategy showed a slight benefit in SNR-50 in comparison to frequency compression strategy strategies.

Conclusions Similar benefit, on aided thresholds and speech identification in quiet, with all the three aided conditions using the three fitting strategies were noted. Improved performance was evident with the SNR-50 measure when using conventional frequency and RIC amplification.

Keywords: conventional frequency amplification, frequency compression amplification, receiver-in-the-canal, aided thresholds, speech identification scores for HF words, SNR-50

Introduction

Individuals with sloping sensorineural hearing loss, present unique amplification challenges. These individuals often exhibit normal hearing sensitivity in the low- to mid- frequencies and have been considered marginal candidates for amplification (Mueller, Bryant, Brown, & Budinger, 1991; Van Vliet, 1999) because of the limitations in the hearing aid technology and normal speech understanding in quiet conditions (Beaner, Grant, & Walden, 2000; Sullivan, Allsman, Nielsen, & Mobley, 1992). In spite of near normal hearing sensitivity through 2000 Hz, listeners with high frequency sensorineural hearing loss exhibit auditory dysfunction beyond loss of audibility, including loudness recruitment, reduced frequency and temporal resolution, and speech recognition deficits (Dancer, Buck, Parmentier, & Hamery, 1998; Findlay, 1976; Henderson & Salvi, 1998). The most common rehabilitation option for these individuals is conventional amplification. Many studies have reported very little or no benefit from high frequency amplification when hearing thresholds exceed 60 dB HL at or above 2 kHz when speech material is presented in quiet (Amos & Humes, 2001; T. Y. Ching, H. Dillon, & D. Byrne, 1998; Hogan & Turner, 1998; Turner & Cummings, 1999; Turner & Hurtig, 1999). While amplification of high frequencies may have some advantage in noise (Plyler & Fleck, 2006), individuals with sloping losses remain at a significant disadvantage in most of the listening environments.

However, providing audibility with regular hearing aid can be difficult to achieve in cases of high frequency hearing losses. (F. Kuk, Keenan, Korhonen, & Lau, 2009) have stated four reasons that make the fitting of hearing aids for individuals with high frequency hearing loss difficult. They are the presence of dead regions in the cochlea, insufficient gain/output capability of the hearing aid, limited frequency bandwidth, and higher chances of acoustic feedback before the desired gain can be reached.

An alternative for high frequency hearing loss is the use of receiver in the canal hearing aid. Taylor (2006) reported significantly higher satisfaction ratings for this type of hearing aid with regard to the quality of their own voice, phone comfort, sound localization, and appearance in two groups of experienced hearing aid users. Hence, such fittings have become increasingly popular in recent years (Fabry, 2006; Staples & Aiken, 2006)

In addition, open fit hearing aids give additional enhancement in the high frequency. The physical separation of the microphone and the receiver in the RIC hearing aid may reduce feedback by minimizing the feedback path ways with in the hearing aid (Ross & Crimo, 1980). The placement of receiver in the canal reduces the residual volume of the canal, thus naturally increasing the sound pressure level in the canal compared with other regular fittings (Hoen & Fabry, 2007). This allows for excellent amplification opportunities even when larger vents are used. The RIC hearing aid provides more available gain before feedback, broader band width and wider fitting range with smooth frequency response than the open fit B.T.E. hearing aid (F Kuk & Baekgaard, 2008). The open fit RIC hearing aid are small enough to be minimally visible and physically unobstructive for most patients, while reportedly providing sufficient gain to improve audibility and understanding for high frequency losses (Gnewikow & Moss, 2006)

Theoretically, RIC instruments should outperform BTE instruments for a number of reasons. Delivery of sound through the thin tube on a BTE instrument can cause peaks in the frequency response, resulting in upward spread of masking (Hoen & Fabry, 2007). Such masking effects are a concern for individuals with typical high frequency hearing loss. These results suggest that RIC instruments should be the preferred choice for such candidates.

Improvements in digital technology and miniaturization of electronic circuits have evolved the hearing aids to accommodate better processing strategies that theoretically can enhance the experience of the users. But research pertaining to the performance of different amplification strategies on the same individual has always been limited. Hence, the present study was initiated to know the performance of these processing strategies in participants having sloping high frequency hearing loss.

Methods

The study was designed to evaluate the influence of three amplification strategies on speech identification, in individuals with sloping SNHL. The three strategies that were evaluated include conventional frequency amplification (CFA), frequency compression amplification (FCA), and receiver in the canal (RIC).

Participants: A total of 45 ears of adults in the age range from 16 to 55 years participated in the study. All the participants recruited for the study were registered clients of All India Institute of speech and hearing (AIISH), Mysuru, India. The participants were native speakers of Kannada language (a Dravidian language of Karnataka state in South India) with a minimum education of 8^{th} standard. The participants had post-lingually acquired high frequency sloping sensorineural hearing loss (SNHL). The air-bone gap was <10dB. Sloping configuration of hearing loss was operationally defined as an audiogram with a difference between the highest and the lowest thresholds of at least 40 dB. All the participants who fulfilled the selection criteria were recruited after obtaining the written informed consent. The ethical guidelines of the All India Institute of Speech and Hearing, India were followed (Venkatesan, 2009).

Test room and tools

The entire testing process was carried out in an air conditioned, sound treated double room suite (American National Standard Institute, 1999). A calibrated double channel clinical audiometer, a calibrated middle ear analyzer, and a personal computer were used. A digital B.T.E hearing aid with the feature for frequency compression, a receiver in the canal hearing aid were used for aided testing. The programming of these hearing aids was done with Hi-Pro connected to the computer with programming software. The speech identification test consisting of words from high frequency Kannada speech identification test developed by Yathiraj and Mascarenhas (2001) was used.

Procedure:

Routine audiological evaluation was carried out to ensure that the participant met the selection criteria. The participant was fitted with a Behind-the-ear digital hearing aid coupled to the test ear using a custom ear mould. The hearing aid was programmed based on the audiometric thresholds and the NAL-Nonlinear (NAL-NL1) prescriptive procedure. After the initial fit, optimization was done by ensuring the audibility of the Ling's six sounds. Finally, the fitting status was saved into the hearing aid (as Program 1, i.e., P1 with CFA). The non-linear frequency compression (NLFC) in the default setting recommended by the software was enabled and saved in the Program 2 (P2 with FCA). The settings of P1 and P2 were stored in the database of the computer. Similarly, the receiver in the canal hearing aid was also programmed, optimized and fitted albeit without an ear mould. The data were collected from each test ear when the BTE hearing aid was in each of the two programs, P1 and P2 in addition to the data collected with RIC hearing aid. That is, only the program that was being tested was enabled during the testing condition and other programs were disabled. Warble tone measurements, Speech Identification Scores and SNR-50 measures were obtained using three hearing aid fitting / amplification strategies. The three fitting strategies were CFA, FCA and RIC.

Aided thresholds for warble tones (at 0.5, 1, 2, 4 and 6 kHz), Speech Identification Scores (SIS) and Signal to noise ratio-50 (SNR-50), were obtained in each of the three aided conditions for each test ear.

Measurement of aided thresholds

The sound field aided thresholds were obtained for warble tones at 0.5, 1, 2, 4, and 6 kHz in each of the three amplification conditions for each test ear. The tones were presented through the loud speaker of the calibrated two-channel audiometer located at one meter and 0^{o} Azimuth from the participant.

Measurement of aided Speech Identification Scores (SIS)

The SIS was measured using recorded high frequency Kannada speech identification test Yathiraj and Mascarenhas (2001). The presentation level was 40 dB SL (re: SRT) through the loud speaker of the audiometer. The SIS was scored as the number of words correctly identified out of 25 words in the list, maximum score being 25. This procedure was

ISSN:2395-1079
Available online at http://www.gjms.co.in/index.php/sajms
South Asia Journal of Multidisciplinary Studies SAJMS June 2017, Vol. 3, No 5
UGC 49956-910

repeated in each of the three aided test conditions for each test ear. This was considered as the SIS for the test ear of the participant in a particular aided condition. The responses were audio recorded and later scored by the main investigator in each of the aided test conditions for each test ear of the participant.

Measurement of SNR-50

The speech was presented at a constant level of 40 dB HL. The level of speech noise was varied in order to obtain the signal to noise ratio (in dB) at which 50 % of the words were identified correctly. This is the speech reception threshold in noise or SNR-50 (Kompis, Krebs, & Häusler, 2006). The SNR-50 was measured in a sound field condition using the recorded Kannada word list.

The data on aided thresholds for five warble tone frequencies, SIS for high frequency word list, and SNR-50 for each test ear of each participant were collected and tabulated. This was subjected to statistical analyses.

Results

The performance data of the 45 test ears in three aided conditions were tabulated and analyzed using Statistical Package for the Social Science software (SPSS for Windows, version 17.0). The data obtained were analyzed under different headings, viz., descriptive statistics of the aided thresholds, SIS for high frequency wordlist, and SNR-50 measures in the three aided conditions. Further, comparison of the three fitting strategies in terms of aided warble tone thresholds, SIS, and SNR-50 was also done.

Table. 1.
Mean, Median, and standard deviation (SD) of aided thresholds, SIS for HF Words and SNR-50 measures in three aided conditions (CFA, FCA & RIC) in the participants (N=45).

Aided Conditions	Frequency	Aided thresholds (in dB HL)			SIS for HF words (Max.=25)			SNR-50 (in dB)		
		Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
CFA	0.5 kHz	37.11	35.00	13.8	18.88	20.00	4.5	2.82	5.00	7.6
	1 kHz	40.55	35.00	15.3						
	2 kHz	46.66	40.00	15.5						
	4 kHz	49.11	45.00	17.6						
	6 kHz	63.00	60.00	18.2						
FCA	0.5 kHz	35.55	30.00	13.1	19.44	20.00	4.2	4.95	7.00	6.2
	1 kHz	40.11	35.00	14.6						
	2 kHz	45.33	45.00	15.3						
	4 kHz	50.44	50.00	17.3						
	6 kHz	56.77	55.00	16.5						
RIC	0.5 kHz	38.7	35.00	12.8	18.77	20.00	4.9	2.5	5.00	7.2
	1 kHz	42.8	40.00	15.1						
	2 kHz	50.1	45.00	16.4						
	4 kHz	47.6	45.00	20.1						
	6 kHz	63.11	55.00	18.5						

Note: CFA=conventional frequency amplification, FCA=amplification with frequency compression, & RIC= Receiver in the canal .

UGC 49956-910

The mean, median, and standard deviation of aided thresholds for the warble tones at different frequencies (0.5 kHz to 6 kHz), SIS for high frequency word list, and SNR-50 in the three aided conditions are depicted in Table 1. The table shows that the mean and median threshold values of the aided thresholds were higher for high frequencies than for low frequencies, in each of the three amplification strategies.

From Table 1, it can be noted that the mean and median of SIS for high frequency words did not show much difference between the amplification strategies. It must be noted here that though the strategies did not improve the speech identification in quiet, there was no reduction in the performance.

The mean, median, and standard deviation of SNR-50 in the participants with three amplification strategies are depicted in Table 1. It can be observed that the SNR-50 values did not show a pattern with reference to the three amplification strategies.

The mean, median, and standard deviation values of the aided thresholds were compared across aided conditions (Table 1). At 0.5 kHz, the median of aided threshold was better with FCA followed by CFA and RIC. At 1k, 2k and 4 kHz , the median of aided thresholds were better with CFA and FCA followed by RIC. At 6 kHz, the median of aided thresholds was better with RIC and FCA followed by CFA. In order to know if these aided conditions were significantly different non-parametric tests were applied. The mean, median, and standard deviation for the speech identification scores with the three amplification strategies are depicted in Table 1. From the table it can be noted that the median value was identical across all the three aided conditions.

The mean, median, and standard deviation using SNR-50 measures in the participants when tested with the conventional frequency amplification, frequency compression, and RIC conditions are depicted in Table 1. It can be noted that the median values (Median=5) were similar for conventional frequency amplification and the RIC amplification . Further, it can be noted that the median value (Median=7) is higher for frequency compression condition when compared to the other two condition tested.

The data collected from the test ears of participants of the current study were subjected to Shapiro Wilk's test of normality to check the pattern of distribution of the data. The test revealed that the collected data did not follow normal distribution for majority of parameters studied ($p<0.05$). In order to know whether the performance was significantly different between the three amplification strategies, non-parametric test of significance, i.e., Friedman test, was administered.

1. Comparison of aided thresholds for the three amplification strategies:

The non-parametric Friedman's test of differences among repeated measures was administered to know if the difference between the amplification strategies was significant. It was noted that there was a significant difference between the amplification strategies on certain performance measures (Table 2). In order to know the amplification condition that brought about the significant difference, Wilcoxon Signed Rank test was administered, whenever indicated.

UGC 49956-910

Table 2. Significant difference (**x^2 and p value**) between the three amplification strategies for aided thresholds, speech identification scores for high frequency words (SIS) and SNR-50, on Friedman's test.

Aided conditions	Measures						
	Aided thresholds			SIS		SNR-50	
	Frequencies	x^2	p value	x^2	p value	x^2	p value
CFA vs. FCA vs. RIC	0.5 kHz	7.85	0.02*	2.90	0.23	16.5	0.00***
	1 kHz	6.61	0.04*				
	2 kHz	22.17	0.00***				
	4 kHz	7.65	0.02*				
	6 kHz	9.10	0.01**				

Note: CFA= conventional frequency amplification, FCA=amplification with frequency compression, RIC= receiver in the canal ; * = p < 0.05; ** = …., *** = p < 0.001.

From Table 2, it can be noted that the amplification strategies brought about a significant difference in the aided thresholds at 0.05 kHz to 6 kHz and SNR-50. The SIS did not show any significant difference between aided conditions. To know if the aided warble tone thresholds differed with different amplification strategies, Friedman's test was administered (Table 2) which revealed that the amplification strategies did bring about significant change at frequencies 0.05 kHz ($p<0.05$), 1 kHz ($p<0.05$), 2 kHz ($p<0.001$), 4 kHz ($p<0.05$) and 6 kHz ($p<0.01$) as given in Table 2.

Table 3. Significant difference (|z| and p values) between three amplification strategies in aided thresholds at 0.5, 1,2, 4, and 6 kHz.

Frequency	Sig.	CFA vs. RIC	CFA vs. FCA	RIC vs.FCA
0.5 kHz	|z|	-1.35	-2.12	-3.29
	p	0.17	0.03*	0.001***
1 kHz	|z|	-2.14	-0.58	-2.7
	p	0.03*	0.55	0.01**
2 kHz	|z|	-2.7	-2.12	-3.4
	p	0.01**	0.03*	0.001***
4 kHz	|z|	-1.5	-1.86	-2.37
	p	0.11	0.06	0.02*
6 kHz	|z|	-0.16	-3.4	-3.3
	p	.87	0.001***	0.001***

Note: CFA= conventional Frequency amplification, FCA=amplification with frequency compression, & RIC= receiver in the canal; * = p < 0.05, ** = p < 0.01, ***=p<0.001.

Wilcoxon's signed rank test (Table 3) revealed that the aided threshold at 0.5 kHz was significantly better in FCA compared to CFA ($p< 0.05$) and RIC ($p< 0.001$) conditions. There

ISSN:2395-1079

Available online at http://www.gjms.co.in/index.php/sajms

South Asia Journal of Multidisciplinary Studies SAJMS June 2017, Vol. 3, No 5

UGC 49956-910

was no significant difference between CFA and RIC as can be seen in Table 3. Further, the result revealed a significantly better aided threshold at 1 kHz in CFA compared to RIC (p<0.05) and RIC compared to FCA (p<0.01) There was no significant difference in the aided threshold at 1 kHz between CFA and FCA.

Further, a significantly better aided threshold was noted at 2 kHz in CFA compared to RIC (p< 0.01), in FCA compared to CFA (p< 0.05), and in FCA compared to RIC (p<0.001)

The aided threshold at 4 kHz was significantly better with RIC compared to FCA (p< 0.05) There was no significant difference in the aided thresholds at 4 kHz between CFA and RIC, and CFA (p>0.05)and FCA (p>0.05) . In addition, it was observed that at 6 kHz, the aided threshold was significantly better with FCA compared to CFA (p< 0.001), FCA was better than RIC (p<0.001). There was no significant difference for CFA and RIC in the aided threshold at 6 kHz.

2. Comparison of SIS Scores for the three amplification strategies:

In order to know if the SIS differed with different amplification strategies, Friedman's test was administered (Table 2) which revealed that the amplification strategies did not bring about a significant change in SIS performance (p>0.05) with the three amplification strategies.

3. **Comparison of SNR-50 for the three amplification strategies:**

To know if the SNR-50 differed with different amplification strategies, Friedman's test was administered (Table 2) which revealed that the amplification strategies did bring about significant change in SNR-50 (p<0.001) between aided conditions. In order to know the strategy that brought about a significant improvement in noise, Wilcoxon's signed rank test was performed (Table 4).

Table 4 Significant difference (|z| and p values) between three amplification strategies in SNR-50.

	Sig.	CFA vs. RIC	CFA vs. FCA	RIC vs. FCA
SNR-50	|z|	-0.25	-3.93	-3.11
	p	0.79	0.000***	0.000***

Note: CFA= conventional frequency amplification, FCA=amplification with frequency compression, RIC = receiver in the canal; * = p < 0.05, *** = p < 0.001.

The results revealed a significantly better performance in noise with CFA (p<0.01) and RIC (p<0.01) when compared with FCA. There was no significant difference between the CFA and RIC conditions as can be seen in Table 4.

Discussion

The purpose of the current study was to investigate the influence of three hearing aid fitting strategies, i.e., conventional frequency amplification - CFA, frequency compression amplification - FCA, and receiver in canal - RIC, on aided thresholds, speech identification scores, as well as SNR-50 measures in individuals with sloping sensorineural hearing loss. .

Comparison of amplification strategies on aided thresholds.

The aided warble tone measurements using conventional frequency amplification (CFA) condition indicate that the participants had better thresholds in the lower frequencies as compared to high frequencies. This may be due to two reasons. The first reason could be attributed to better audibility in the low frequencies. The second reason for the difference may be attributed to variability in measuring hearing thresholds that arise due to artifacts with sloping hearing loss (Walker, 1995). The artifacts reported by them are the inter modulation distortion which occurs at the loudspeaker or at the hearing aid at a high output level. This results in an audible distortion product that is much lower in frequency and level. The present study agrees with the report by Walker (1995), that there would be such 'measurement variabilities' which would have influenced the threshold measurements especially in sloping sensorineural hearing loss.

Further, the aided warble tone thresholds using frequency compression amplification (FCA) strategy also reveals better thresholds at lower frequencies than at the higher frequencies. Further, at 6 kHz a better threshold was obtained this may be due to the fact that frequency compression has helped in improving the audibility due to compression of high frequencies. Such a finding of better aided threshold at high frequencies has been reported in literature (Glista et al., 2009; Hazzaa, Hassan, & Hassan, 2015; Wolfe, Caraway, John, Schafer, & Nyffeler, 2009) using non-linear frequency compression.

Further, the aided warble tone thresholds using receiver in the canal (RIC) strategy reveals better thresholds at lower frequencies than at higher frequencies. Also at 6 kHz a better threshold was noted when compared to CFA, this may be due to the fact that RIC has helped perception of 6 kHz tone because of wide band width as well as higher gain before feedback. Such findings have been reported in literature (Alworth, Plyler, Reber, & Johnstone, 2010; Prakash et al., 2013) using CRT amplification.

Comparison of amplification strategies on aided speech identification scores.

In the present study, speech identification measurements involving the CFA, FCA, and RIC revealed that the SIS were comparable across all the three strategies. However, a slightly higher mean value was obtained for frequency compression strategy (FCA) compared to the other two strategies. Similar findings were reported by Ellis and Munro (2015) on seven subjects. They showed that frequency compression provides additional benefits in speech recognition than that conferred by conventional amplification strategies.

In contrast, Simpson, Hersbach, and McDermott (2006), reported that less than 50% of their participants having sloping sensorineural hearing loss showed a significant improvement in speech recognition score ($p<0.05$), when tested with a conventional frequency and frequency compression hearing aid for monosyllabic words in their subjects. Further, they reported that on an average, the use of the frequency compression provided similar recognition of monosyllabic words and consonants as regular/conventional hearing aids, in their participants.

Further, the aided speech identification scores using RIC strategy reveals similar scores as CFA and FCA. Such findings of improved scores in quiet condition have been reported in literature (Alworth et al. (2010), using RIC. The improvement is not significant because of ceiling effect observed in such fittings.

Comparison of amplification strategies on SNR-50.

The findings of SNR-50 measurements using CFA, FCA, and RIC indicate that there was a significant difference between CFA and FCA, and, RIC and FCA; with the FCA being poorer than CFA and RIC. The results of the present study are in discordance with studies which claim similar performance in participants with CFA and FCA for speech recognition in noise (F. Kuk et al., 2009; H. J. McDermott & Dean, 2000; Robinson, Goddard, Dritschel, Wisley, & Howlin, 2009). Since, results revealed that the participants in the present study performed poorly using FCA. This finding is in agreement with the findings of that reported by J. H. McDermott (2011). He reported that the frequency lowering actually degraded speech recognition in noise. A consequence of frequency compression is that it may make audible high frequency noise that would have otherwise been inaudible with conventional amplification, which could impair speech understanding (Wolfe et al., 2010). The findings of the present study are in agreement with a study by Simpson et al. (2006). They found that when testing speech in the presence of noise, the frequency compression scheme provided only limited benefit to listeners who had steeply sloping hearing losses.

Further, the SNR-50 measure using RIC strategy reveals similar performance as CFA. Such findings of improved performance in noise condition have been reported in literature (Mondelli, Garcia, Hashimoto, & Rocha, 2015), using RIC amplification. Although the improvement is not significant but preference for such fittings was found in subjective evaluations Prakash et al. (2013).

Conclusions

The performance of the participants having sloping hearing loss was compared with three aided conditions (CFA, FCA, and RIC). The data from three test measures (aided thresholds, speech identification scores for high frequency words, and SNR-50) tested with CFA, FCA, and RIC were subjected to analysis. . A small improvement in mean aided threshold value at 6 kHz was noted with FCA and RIC when compared to CFA. For speech identification in quiet, the mean SIS was slightly higher in frequency compression strategy compared to the performance with the other two strategies. There was no difference in SIS with CFA and RIC strategies. Further, the speech perception in noise was found to be best in CFA and RIC conditions followed by FCA condition.

Acknowledgement: The authors would like to thank the All India Institute of Speech and Hearing, Mysuru, India for providing facilities to carry out the present study. We acknowledge all the participants for their kind co-operation.

Conflict of Interest: Authors declare no conflict of interest.

References

Alworth, L. N., Plyler, P. N., Reber, M. B., & Johnstone, P. M. (2010). The effects of receiver placement on probe microphone, performance, and subjective measures with open canal hearing instruments. Journal of American Academy of Audiology, 21(4), 249-266. doi: 10.3766/jaaa.21.4.4

American National Standard Institute. (1999). ANSI S3.1-1999 (R2013) Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms. New York:: American National Standards of the Acoustical Society of America.

Amos, N. E., & Humes, L. E. (2001). The contribution of high frequencies to speech recognition in sensorineural hearing loss. In D. J. Breebaart, A. J. M. Houtsma, A. Kohlrausch, V. F. Prijs & R. Schoonhoven (Eds.), Physiological and psychophysical bases of auditory function (pp. 437-444). Maastricht, The Netherlands: Shaker.

Beaner, S. L., Grant, K. W., & Walden, B. E. (2000). Hearing aid benefit in patients with high - frequency hearing loss. Journal of American Academy of Audiology, 11, 429-437.

Ching, T. Y., Dillon, H., & Byrne, D. (1998). Speech recognition of hearing-impaired listeners: predictions from audibility and the limited role of high-frequency amplification. Journal of Acoustical Society of America, 103(2), 1128-1140.

Ching, T. Y. C., Dillon, H., & Byrne, D. (1998). Speech recognition of hearing-impaired listeners: Predictions from audibility and the limited role of high-frequency amplification. The Journal of the Acoustical Society of America, 103(2), 1128-1140. doi: 10.1121/1.421224

Dancer, A., Buck, K., Parmentier, G., & Hamery, P. (1998). The specific problems of noise in military life. Scandinavian Audiology, 27, 123-130.

UGC 49956-910

Ellis, R. J., & Munro, K. J. (2015). Predictors of aided speech recognition, with and without frequency compression, in older adults. International Journal of Audiology, 54(7), 465-475. doi: 10.3109/14992027.2014.996825

Fabry, D. A. (2006). Facts vs. Myths: 'The skinny' on the slime tube open fittings. The Hearing Review, 13(5), 20-25.

Findlay, R. C. (1976). Auditory dysfunction accompanying noise-induced hearing loss. Journal of Speech and Hearing Disorders, 41, 374-380.

Glista, D., Scollie, S., Bagatto, M., Seewald, R., Parsa, V., & Johnson, A. J. (2009). Evaluation of nonlinear frequency compression: clinical outcomes. International Journal Audiology, 48(9), 632-644. doi: 10.1080/14992020902971349

Gnewikow, D., & Moss, M. (2006). Hearing aid outcomes with open and closed canal fittings. The Hearing Journal, 59(11), 50-56.

Hazzaa, N., Hassan, D. M., & Hassan, A. (2015). Evaluation of non-linear frequency compression hearing aids using speech P1-cortical auditory evoked potential. Hearing, Balance and Communication, 14(1), 36-43. doi: 10.3109/21695717.2015.1079984

Henderson, D., & Salvi, R. J. (1998). Effects of noise exposure on the auditory functions. Scandinavian Audiology,, 27, 63-73.

Hoen, M., & Fabry, D. (2007). Hearing aids with external receivers: Can they offer power and cosmetics? The Hearing Journal, 60(1), 28-34. doi: 10.1097/01.HJ.0000324489.80400.b2

Hogan, C. A., & Turner, C. W. (1998). High-frequency audibility: Benefits for hearing-impaired listeners. The Journal of the Acoustical Society of America, 104(1), 432-441. doi: 10.1121/1.423247

Kompis, M., Krebs, M., & Häusler, R. (2006). Speech understanding in quiet and in noise. . International Journal of Audiology., 54(6), 445-450.

Kuk, F., & Baekgaard, L. (2008). Hearing aid selection and BTEs: Choosing among various 'open ear' and 'receiver-in-canal' options. The Hearing Review, 15(3), 22-36.

Kuk, F., Keenan, D., Korhonen, P., & Lau, C. C. (2009). Efficacy of linear frequency transposition on consonant identification in quiet and in noise. Journal of American Academy of Audiology, 20(8), 465-479.

McDermott, H. J., & Dean, M. R. (2000). Speech perception with steeply sloping hearing loss: effects of frequency transposition. British Journal of Audiology, 34(6), 353-361.

McDermott, J. H. (2011). A Technical Comparison of Digital Frequency-Lowering Algorithms Available in Two Current Hearing Aids. PLoS One, 6(7). doi: 10.1371/journal.pone.0022358.t001

Mondelli, M. F., Garcia, T. M., Hashimoto, F. M., & Rocha, A. V. (2015). Open fitting: performance verification of receiver in the ear and receiver in the aid. Brazilian Journal of Otorhinolaryngol, 81(3), 270-275. doi: 10.1016/j.bjorl.2014.08.013

Mueller, H. G., Bryant, M. P., Brown, W. D., & Budinger, A. C. (1991). Hearing aid selection for high frequency hearing loss. In G. Studebaker, F. Bess & L. Beck (Eds.), The Vanderbilt hearing aid report II (pp. 269-286). Parkton, MD.

Plyler, P. N., & Fleck, E. L. (2006). The effects of high-frequency amplification on the objective and subjective performance of hearing instrument users with varying degrees of high-frequency hearing loss. Journal of Speech Language and Hearing Research, 49(3), 616-627. doi: 10.1044/1092-4388(2006/044)

Prakash, S. G. R., Aparna, R., Rathna Kumar, S. B., Madhav, T., Ashritha, K., & Navyatha, K. (2013). Sensori-Neural Hearing Loss Client's Performance with Receiver-In-Canal (RIC) Hearing Aids. International Journal of Otolaryngology and Head & Neck Surgery, 02(02), 68-73. doi: 10.4236/ijohns.2013.22017

UGC 49956-910

Robinson, S., Goddard, L., Dritschel, B., Wisley, M., & Howlin, P. (2009). Executive functions in children with autism spectrum disorders. Brain Cognition, 71(3), 362-368. doi: 10.1016/j.bandc.2009.06.007

Ross, M., & Crimo, R. (1980). Reducing feedback in a post-auricular hearing aid by implementing the receiver in an earmold. Volta Review, 40-44.

Simpson, A., Hersbach, A. A., & McDermott, H. J. (2006). Frequency-compression outcomes in listeners with steeply sloping audiograms. International Journal of Audiology, 45(11), 619-629. doi: 10.1080/14992020600825508

Staples, C., & Aiken, S. (2006). Where did my gain go? Thin tube open Fit BTE Verification., from http://www.bernafon.ca/eprise/main/ca_en/_downloads/Bernafon_Gain_Tech_Topic.pdf.

Sullivan, J. A., Allsman, C. S., Nielsen, L. B., & Mobley, J. P. (1992). Amplification for listeners with steeply sloping, high-frequency hearing loss. Ear and Hearing, 13(1), 35-45.

Taylor, B. (2006). Real-world satisfaction and benefit with open-canal fittings. The Hearing Journal, 59(11), 74-82.

Turner, C. W., & Cummings, K. J. (1999). Speech audibility for listeners with high-frequency hearing loss. American journal of Audiology, 8(1), 47-56.

Turner, C. W., & Hurtig, R. R. (1999). Proportional frequency compression of speech for listeners with sensorineural hearing loss. Journal of Acoustical Society of America, 106(2), 877-886.

Van Vliet, D. (1999). Is there a hearing aid that can…? The Hearing Journal, 52(10), 100.

Venkatesan, S. (2009). Ethical guidelines for bio-behavioural research involving human subjects Mysore, India: All India Institute of Speech and Hearing.

Walker, G. (Ed.). (1995). Technical considerations of sound field audiometry. In: Sandlin R, ed: Handbook of Hearing Aid Amplification, vol 1, ch. 6 pp 147-164. : Singular Publishing Group, (Vol. 1): San Diego.

Wolfe, J., Caraway, T., John, A., Schafer, E. C., & Nyffeler, M. (2009). Study suggests that non-linear frequency compression helps children with moderate loss. The Hearing Journal, 62(9), 32-37. doi: 10.1097/01.HJ.0000360848.64207.fc

Wolfe, J., John, A., Schafer, E., Nyffeler, M., Boretzki, M., & Caraway, T. (2010). Evaluation of nonlinear frequency compression for school-age children with moderate to moderately severe hearing loss. Journal of American Academy of Audiology, 21(10), 618-628. doi: 10.3766/jaaa.21.10.2

Yathiraj, A., & Mascarenhas, E. K. (2001). High frequency Kannada speech identification test (HF-KST). Masters dissertation. University of Mysore.