THE EFFECT OF INSERTION GAIN AND PREFERRED GAIN ON SPEECH INTELLIGIBILITY

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CERTIFICATE

This is to certify that the dissertation entitled "**The Effect of Insertion Gain and Preferred Gain on Speech Intelligibility**" is the bonafide work submitted in part fulfillment for the degree of Master of Science (Audiology) of the student (Registration No. 16AUD022). This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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This is to certify that the dissertation entitled "**The Effect of Insertion Gain and Preferred Gain on Speech Intelligibility**" has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in any other University for the award of any Diploma or Degree

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DECLARATION

This is to certify that this dissertation entitled "**The Effect of Insertion Gain and Preferred Gain on Speech Intelligibility**" is the result of my own study under the guidance of Dr. Geetha C, Reader in Audiology Department of Audiology, All India Institute of Speech and Hearing, Mysuru, and has not submitted earlier in any other University for the award of any Diploma or Degree.

Mysuru, **Register No: 16AUD022**

April, 2018.

Dedicated to the

Living God's my

Dear Appa, Amma.

also to my Brother

& My Guide

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Abstract

Fine-tuning of hearing aids of individuals with hearing impairment has an important role particularly in speech perception. Use of real ear measurements (REMs) by means of probe microphone recordings for fitting hearing aid to an individual is considered to be a gold standard method for achieving appropriate gain settings. Achieving preferred listening level is considered to be another important step to evaluate the clinical efficacy of hearing aid fittings. The present study aimed to evaluate the difference in insertion gain and difference in speech identification scores between three different gain settings. They are first fit condition (where, the hearing aid was programmed according to the NAL-NL1 prescriptive procedure with no fine tuning from the initial fit), matched target (prescriptive) condition (where fine tuning was made to match the REM system REIG curve to the target gain as prescribed by NAL-NL1 equation) and preferred condition (which the person chooses or prefers for listening to hearing aid amplified speech and routine hearing aid evaluation) with NAL – NL1 prescriptive formulae. Fifteen ears in the age range of 33 to 53 years with mild to moderate flat sensorineural hearing impairment were included. Insertion gain and speech identification scores across three different gain settings mentioned above at three different input levels. The results revealed that matched target condition in an individual was found to give more insertion gain compared to the preferred condition and first fit condition. In speech identification measures preferred condition was found to be better compared to first fit condition and matched target conditions. It can be concluded that the NAL NL- 1 prescriptive formula, the preferred gain settings were positively influencing the speech perception in an individual at different input levels

Keywords: *Real Ear Insertion Gain, preferred listening level, Speech identification scores, Gain setting.*

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CHAPTER 1

INTRODUCTION

According to National sample survey 58th round (NSSO, 2002), hearing loss is one of the major causes of sensory deficits in India. Eighty percentage of the hearing-impaired population lives in low and middle income countries as outlined by WHO (2006). Around 5.3% of the world's population is found to experience the disabling hearing loss (Varshney, 2016). Untreated hearing loss is found to have its adverse effects on overall functioning and quality of life that includes social isolation, cognitive, and functional - communication decline among others (Lin et al., 2011).

Hearing aid fitting is one of the primary options of rehabilitation of individuals with sensorineural hearing loss. Hearing aid fitting procedure is considered as an iterative process where audiologists are confronted frequently with the task of selecting and fitting an appropriate amplification device with the help of prescription targets. These prescriptive procedures are meant to be based on the procedure which calculates the target gains derived from the individual's audiometric data (hearing threshold, most comfortable loudness level, and loudness discomfort level among others).

One of the major aims of these prescriptive approaches is to deliver appropriate gain to individuals with hearing impairment to achieve good speech perception through hearing aid. First approximations of the gain required are given by the prescriptive formulae, but these methods do not seem to eliminate the need for fine tuning of hearing aid (Dillon, 2001). When the prescribed gain becomes a good approximation of the gain which is preferred by an individual to listen, the number of trials and errors made by the clinician are reduced and also saves time (Dillon, 2001). A series of studies done by Keisder et al. (2001, 2005, 2006, 2007, and 2008) reported that preferred gain by the adult experienced hearing aid users was lower by 6 dB than the prescribed target. In case of children similar results were reported by Ching, Scollie, Dillon and Seewald (2010).

The use of real ear measurements (REMs) by means of probe microphones recordings for fitting hearing aid to an individual is considered to be a gold standard method into achieve appropriate gain settings. Dillon and Keidser (2003) suggested that real ear measurements are recommended to be used in the verification process in order to make sure that the prescribed gain equals the measured performance of hearing aid in the individuals' ear.

Amlani and Gessling (2016) verified the effect of using REM on hearing aid user's satisfaction by comparing it with the manufacturer's Quick-fit specifications. They found that use of REM resulted in increased self-perceived benefit from the hearing aid and increases the satisfaction with the audiologist by improving the attitude towards the amplification process. Thus, they concluded that inclusion of REM in clinical practice of prescribing and fitting a hearing aid to a hearing impaired individual improves the hearing healthcare experience for both patients as well as the clinicians.

Hawkins and Cook (2003) examined the accuracy of hearing aid performance in an individual as predicted by the fitting software where they compared with two conditions; one which is simulated with respect to the manufacturers' fitting software and second was the measured with 2cc coupler and REIG were values obtained though REM. They found that the low and high frequencies were over-estimated from the actual 2 cc coupler measurements and high frequencies were over-estimated from the actual real-ear gain measurements.

Swan and Gatehouse (1995) used REIG measures obtained through real ear measurements (REM) on 319 individuals to find whether REIG was a precise measure to find improperly fit hearing aids and whether REIG measures can be incorporated to make the fitting changes needed to match target. They found that among 319 individuals, 181 individuals failed to fall within the 10 dB criteria of the target gain at one or more frequencies checked between 250 Hz to 3000 Hz recommended by NAL formula. Thus, they concluded that inclusion of REIG measurements is essential according to the NAL prescriptive target values to ensure an accurate hearing aid fitting.

In a similar study done by Aazh and Moore (2007), it was found that at higher frequencies about 64% of the hearing aids failed to meet NAL-NL1 REIG target values and after fine tuning of the gain settings of those hearing aids, 83% of the hearing aids met REIG values. Thus, these studies when combined conclude that a majority of hearing aid fittings were able to meet target insertion gain when REMs were used.

Achaiah (2011) compared the preferred gain over the prescribed gain settings of NAL – NL1 and DSL [i/o], among the experienced hearing aid users. They reported that highest scores were obtained at the preferred gain settings. They also reported that higher gain was preferred by the listeners over the prescribed gain especially at mid and high frequencies. Majority of the adult hearing aid users prefer different gain settings than that of the gain settings prescribed by NAL–NL1. Thus, it can be inferred that fine tuning of initial fit over in a hearing impaired individual has an important role particularly in speech perception.

1.1 Need for the study

1.1.1 Need to compare insertion gain and speech intelligibility at different gain settings.

Prescriptive equations are considered to be one of the necessary tools which enable accurate adjustments of gain for individuals with hearing impairment. Nevertheless, Aarts and Caffee (2005) stated that real ear measurements simulated in hearing aid programming software tend to overestimate individually obtained values.

Mueller (2005) also stated that the individual's benefit is greater if the targets are found to be well matched. Dillon (2001) stated that comparison of the prescribed gain with individuals preferred gain is one of the key methods to determine the efficacy of fitting formula. Majority of these studies have compared insertion gain across different programmed gain settings. Speech intelligibility has not been compared. Speech intelligibility plays a vital role in speech audibility or loudness, for subjects with sensorineural hearing loss and hence gain adjustments have to result in best speech intelligibility scores. Minakshi (2006) investigated the effects of preferred as well as prescribed gain on speech perception in noise using the NAL- NL1 and DSL i/o to determine the gain differences and the speech perception outcome within these two measures. They found that the individual's preferred higher gain at mid frequencies, and lower gain at high and low frequencies. With respect to SNR estimation measures, they found that preferred as well as prescribed gain measures do not shed its effect on the speech perception measures.

Achaiah (2011) compared the preferred gain over the prescribed gain settings of NAL – NL1 and DSL [i/o], among the experienced hearing aid users. They reported that highest scores were obtained at the preferred gain conditions. They also reported that higher gains were preferred by the hearing-impaired individuals over the prescribed gain especially at mid- and high- frequencies.

Thus, it can be inferred that fine-tuning of initial fit over in a hearing impaired individual has an important role particularly in speech perception. In many hearing aid protocols, especially paediatric protocols include insertion gain as the main hearing aid fitting procedure. In non-verbal cases such as children with congenital hearing loss, no speech perception measures can be used to fit hearing aids, hearing aid fitting majorly relies on tests such as insertion gain measures. While the difference between the target gain and prescribed gain is well documented, the difference between insertion gain that is matched to the target curve of the prescriptive equation and preferred gain is not well understood and this disagreement between the preferred gains over the insertion gain may have its effect on speech perception also.

Hence, it is important to present evidence to see the benefits provided by each of these parameters. Measuring speech intelligibility at insertion gain and comparing that of preferred gain is necessary. Though there are ample amount of literature that discuss about the importance of real ear measurements on verification and validation of hearing aids, the literature on the REIG and the amount of fine tuning required for the optimum in speech intelligibility are scanty.

1.1.2 Need for using International Speech Test Signal (ISTS) stimuli.

In the current study, along with the comparison of preferred gain and insertion gain using International Speech Test Signal stimuli, speech intelligibility will also be compared. Earlier, stationary signals such as sine wave frequency sweeps and unmodulated noise signals were used to measure the performance of hearing aids. ANSI 3.22 and IEC 60118 stated that these signals permit reproducible measurement.

However, speech signals are the key stimuli which a hearing aid user encounters daily for his/her communication needs and these stimuli are processed differently from that of the stationary signals such as composite signal or digi-speech in non-linear hearing aids.

European Hearing Instrument Manufacturers Association (EHIMA) developed standardized test measurement procedure called as ISTS since it allows hearing instruments to be programmed to real-life settings. Arehart, Kates, and Anderson (2011) found high correlation between these two stimuli, thus reinforcing the validity of using ISTS. Hence, in the present study, ISTS will be used for insertion gain measurements.

1.2 Aim of the study

The aim of the present study was to evaluate the difference in insertion gain and difference in speech identification scores between first fit gain, preferred gain setting and the gain setting that matched target gain in REM.

1.3 Objectives of the study

The objectives were-

1. To compare REIG measurements at three different gain settings. They are
   i. First fit condition - Where, the hearing aid was programmed according to the NAL-NL1 prescriptive procedure with no fine tuning from the initial fit
   ii. Matched target (prescriptive) condition - Where fine tuning was made to match the REM system REIG curve to the target gain as prescribed by NAL-NL1 equation and
   iii. Preferred condition - Which the person chooses or prefers for listening to hearing aid amplified speech and routine hearing aid evaluation at three different input levels (45 dB, 65 dB & 80 dB), and

2. To compare speech identification scores (SIS) between three different gain as mentioned above at three different input levels (45 dB, 65 dB & 80 dB SPL).

CHAPTER 2

REVIEW OF LITERATURE

Persons with sensorineural hearing loss most often have difficulty in understanding speech. The amount of enhancement required for a hearing aid user to understand speech like a normal person in noisy situation is approximately 4-10 dB (Dillion, 2001; Hamacher et al., 2005). The primary option of rehabilitation of individuals with sensorineural hearing loss is hearing aid fitting. The ultimate goal of fitting a hearing aid is to make best use of an individual's residual hearing which might have an impact on the individual's everyday communication. Providing individuals with appropriate amplification comprises of programming hearing aids to a necessary amount of amplification. This is usually done with the help of a prescriptive formula/ equation.

2.1 Use of various prescriptive formulae for hearing aid fitting

Prescriptive formulae derive target gains from the audiometric information of an individual. There are many such equations. Prescriptive equations have now evolved to be a common practice in the hearing aid fitting. For non-linear hearing aids, threshold based procedures such as FIG6 (Killion and Fikret, 1993), NAL-NL1 (Dillon, 1999), and DSL [i/o] (Cornelisse, Seewald and Jamieson, 1995) are considered, while supra-threshold procedures include LGOB (Allen, Hall and Jeng, 1990), partly DSL [i/o] as well as IHAFF (Cox, 1995). The amount of prescribed gain usually varies among the manufacturers for the same degree and configuration of hearing loss. It is also affected by the various factors such as hearing aid experience, type of hearing aid, gender and selected prescriptive method. Braida et al (1979) in his review mentioned that frequency gain characteristics according to the prescriptive methods were formulated and assessed with the main goal of users' ability to understand speech. Various prescriptive procedures have been developed and advocated over the past years, which predict the real ear insertion gain (REIG) based either on loudness equalization or speech intelligibility (Dillon, 2001).

Among the procedures mentioned above, NAL-NL1 and DSL [i/o] are the most commonly used procedures for prescribing hearing aids and considered as a good place to begin a hearing aid fitting (Mueller, Ricketts, and Bentler, 2016). Though these two methods result in similar speech intelligibility and loudness values, they tend to provide different insertion gain (Johnson & Dillon, 2011). Mueller (2005) opined that in order to value a prescriptive method, it is important to measure how well the fitting of those hearing aid counterparts the prescription itself. Modernizing of Hearing Aid Service (UK) guidelines suggest that fitting of hearing aids to a prescription should be within +/- 5 dB at low and mid frequency regions, and +/- 8 dB at high frequency regions (Aazh & Moore, 2007). For individuals with similar hearing loss, the amplification characteristics are altered by the targets prescribed by the different fitting formulas (Keidser, Brew and Peck, 2003).

Ching et al (2010) evaluated the effectiveness of NAL – NL1 and DSL v.4 on 48 children. They found that gains were significantly higher in hearing aids fitted with DSL v.4 by 7 dB than with NAL-NL1 procedure. They also concluded that irrespective of difference in overall gain provided, these both formulas were similarly effective in terms of laboratory and real-life performance and preference.

Johnson and Dillon (2011) found that when averaged across the five sensorineural hearing losses, NAL-NL2 and DSL m[i/o] methods provided an estimated 96% predicted speech intelligibility at +10 dB SNR, 77% at 0 dB SNR, and 7% at a -10 dB SNR for sentence level material of the Connected Speech Test (Cox, Alexander & Gilmore, 1987) with a transfer function from Humes (2002).

2.2 Use of real ear measurements for hearing aid fitting

The main objective of hearing aid fitting is to provide adequate and favorable listening level to individuals with hearing impairment. Real ear measurements (REMs) using probe microphones following the prescriptive target is recognized as a gold standard method for hearing aid fitting by many audiologists. REM is considered to be one of the best practices for hearing aid fitting. Beck (2010) in his study reported that satisfaction rate in hearing aid user increased up to 18% when the hearing aid gain was verified with the real ear measurements. It is an objective and precise method to match the gain of a hearing aid in an individual's ear to the target gain provided by prescriptive equations.

Most prescriptive procedures predict gain obtained by placing the hearing aid in the real ear (also known as Real ear insertion gain (REIG) either on the basis of loudness equalization or speech intelligibility (Dillon, 2001). Responses such as Real Ear Aided Response (REAR) or Real Ear Insertion Gain (REIG) measures are considered to be one of the frequently used methods of comparing the hearing aid gain to that of the targets based on the individual thresholds (Galster, 2011).

Aarts and Caffee (2005) evaluated the Manufacturer's fitting software and its accuracy on predicting the REAR values. Their results showed that REAR values as mentioned by the manufacturer's fitting software were not accurate, almost for all individuals who participated in their study. Therefore they concluded that the present study results are consistent with recommendations audiologists should make use of real ear measurements as an evidenced based 'best practice' while verifying the benefit of hearing aid in an individual rather than depending on manufacturer fitting software (Hawkins & Cook, 2003; Mueller, 2003; Van Vliet, 2003).

REIG measurement remains an accurate and precise technique that predicts how well a hearing aid matches with prescription target of an individual, and for fine-tuning of a hearing aid to correctly match (Seewald, Moodie, Sinclair and Scollie, 1999). Despite the importance of REIG measurements, probe microphones are used considerably lesser for the confirmation of the fitting accuracy. Therefore, Abrams, Chisolm, McManus and McArdle (2012) studied the effect of hearing aid fitting method on the self-perception of hearing aid benefit, between the initial and the verified prescriptive gains. APHAB was administered on twenty two hearing impaired individuals who are using hearing aids in order to assess the perceived benefit from hearing aids. Apart from the measures on benefit, they also found that there was a significant reduction in REAR with the initial fit approach which had its impact on the APHAB outcomes. The outcome measures obtained through the latter technique was way better relative to that of initial fit method. Thus, they concluded that the use of the verified prescription has a major role on the self-perceived hearing aid outcomes rather than the initial fit approach.

As supported from the above studies and their findings, there are plenty of studies which give strong evidence in support of REM. Irrespective of these findings; there is still a dispute that whether obtaining REIG measurements are necessary with the advancements in modern hearing aids.

2.3 Differences between target gain and insertion gain

There are studies indicating the possibility of differences between the insertion gain and prescriptive targets predicted gain. Aarts and Caffee (2005) found that there was an overestimation of individually obtained real ear measurement values obtained through hearing aid programming software under the simulated condition. Campos, Mondelli and Ferrari (2011) compared the computer-generated (simulated) insertion gain in HA programming software with that of the REIG measurements. They found that insertion gain measurements obtained through the HA programming software was higher than the REIG measurements obtained with the use of probe microphone measurements.

Leijon, Eriksson and Bech (1984) investigated the insertion gain preferred by 12 individuals with moderate sensorineural hearing impairment. Assessment was carried out in two situations such as everyday listening situations and acoustically specified test situations. From their test findings, they concluded that there was overestimation of preferred insertion gain in the mid frequency region compared to that of the prescriptive gain.

Hawkins and cook (2003) investigated the performance of a hearing aid as estimated through the hearing aid fitting software and they concluded that there was an over estimation of actual real ear gain at high frequencies. In lower frequencies the differences between the actual and insertion gain measurements varied between +/- 5 dB whereas in the higher frequencies especially at 4 kHz the gain differences were around 10 dB than the simulated insertion gain. Thus, they concluded that simulated gain values through the hearing aid fitting software can be used only during initial times and use of individual validation measurements are necessary later on. Thus the poor discrepancy amongst predicted and measured REAR values as reported by Aarts & Caffee (2005) as well as Hawkins and cook (2003) might shed its effect on individuals' daily communication.

Christensen and Groth (2008) quoted that failure to use the probe microphone REM was the main mistake to accurately measure the acoustic output or gain of the hearing aids in the individual's ear canal. Swan and Gatehouse (1995) assessed the importance of using real ear measures to fit hearing aids according to the prescriptive targets, where they verified whether REIG was a precise measure to discover improperly fit hearing aids, and following, whether REIG measures could be used to make the fitting changes necessary to match target values. They concluded that inclusion of REIG measurements is essential according to the NAL prescriptive target values to ensure an accurate hearing aid fitting. Norman and James (2000) assessed the differences amongst insertion gain and coupler measurements and the precision of hearing aid fitting methods that incorporates RECD (Real Ear to Coupler Differences). In this study, they found that the differences cannot be predicted accurately among insertion gain and coupler gain measurements produced by the same hearing aids. They also concluded that the estimation of the insertion gain from the other aid could vary from the actual insertion gain by 10 dB or more at some frequencies.

Despite the importance of REIG measurements, probe microphones are used considerably lesser for the verification of the fitting accuracy. In a study done by Abrams, Chisolm, McManus and McArdle (2012) during a period of eight weeks, observed whether one's own self-perception of the benefit provided by the hearing aid differed with respect to the hearing aid fitting method when measured through APHAB especially, in settings with respect to manufacturer's initial-fit methodology and verified recommendation method. Twenty-two individuals with experience in hearing aid usage participated in their study, where eleven participants were fitted with the initial fit (manufacturer's), whereas the other eleven participants where fit to the verified prescription by means of probe-microphone measurement. Results revealed that the outcome measures obtained with the verified prescriptive technique were way better matched to that of initial fit approach. Thus they concluded that the use of the verified prescription has a major role on the self-perceived hearing aid effects rather compared to that of the initial fit approach.

From the previous studies and findings (e.g. Aazh and Moore, 2007; Aarts and Caffe, 2005; Hawkins and Cook, 2003) it is clear that, the gain settings provided by the prescriptive formula or manufacturers initial fit algorithm isn't just sufficient to provide the best outcomes and often provides less gain during the initial hearing aid fitting. After the hearing aid fitting of an individual, an assessment of how well the prescriptive formula supports hearing in a controlled and the acceptability of a prescription (preferred listening level) by an individual may reflect clinical usefulness in rehabilitation of these individuals.

2.4 Use of preferred listening level

Preferred listening level (PLL) is considered to be one of the methods to evaluate the clinical efficacy of hearing aid fittings. Cox & Alexander (1994) defined preferred level as “the sound pressure level at the eardrum that the person chooses or prefers for listening to hearing aid-amplified speech”. One of the major objectives of the prescriptive formulae is to provide the gain what actually the hearing impaired individual needs rather than what an audiologist predicts that might yield a better speech recognition. Preferred listening level is a compromise amongst comfort, intelligibility and other factors. It also represents a correlation between the subjective measures with that of the objective measure (Cox, 1982).

According to clinical reports, individuals with experience in hearing aid usage usually prefer more gain compared to that of the individuals who are naive hearing aid users (Convery, Keidser and Dillon, 2005). Humes (1986) assessed the ability of different prescriptive methods (POGO, NAL, NAL –R, Berger, COX, CID, Bragg, Libby, Shapiro, Vandy) to provide the absolute gain and relative gain as preferred by the hearing impaired listener to optimize the speech recognition performance in an hearing impaired individual.

The prescribed gain values from the above selection procedure were compared with that of the preferred insertion gain values obtained by Leijon et al. (1984) with the help of miniature microphone method in REM (Ringdahl & Leijon, 1984). Leijon et al. found that based on absolute gain values Vandy procedure had the best approximation of preferred insertion gain values followed by the COX, Libby and CID methods. In case of prediction of insertion gain based on the relative gain, Libby and Vandy procedures provided the best approximation. Byrne (1983) mentioned that if the hearing aid user is given the control over volume control, then the prescribed overall gain is not crucial. Challenging is to set an optimal frequency response shape that differs with the preferred listening level of the individual

Scollie et al. (2005) compared the difference between PLL and target listening levels as predicted with the help of DSL v4.1 recommendation in both children's and adults. They observed that children's mean preferred listening levels normally fell within 2 dB of the target listening levels, but in case of individuals with experience in hearing aid usage and to that of the individuals who are naive hearing aid users, the mean preferred listening levels fell within 9 dB and 11 dB below target level.

In a study carried out by (Byrne & Dillon, 1986), on ninety-eight new and seventy-seven experienced hearing aid users where they compared difference between PLL and target listening levels from the NAL-R. Their findings put forward that the naive hearing aid users usually preferred a lesser amount of gain than the individuals with experience in hearing aid usage and the difference in the preferred gain among the two populations were not more than 2 dB Similar results were also found in other research works carried out by Marriage et al (2004) where the preferred gain was 2.6 dB lower for new hearing aid users. Keisder and Dillion (2006) on his study commented that preferred gain with respect to NAL-NL 1 at 65 dB input was correlating for 49% of the hearing aid users; whereas for 5% of the population it was found to be non-sufficient and for the remaining 46% of the population, the gain prescribed by the NAL-NL 1 was found to be 3dB more. Even though preferred listening level is considered to be one of the measures of hearing aid outcome, it is found to access only the effectiveness. To find the effectiveness of the hearing aid fittings and its effect on speech perception in an individual with hearing impairment in a real life situation is also important. Polonenko et al. (2010) assessed how well the DSL v5.0a approximates its correlation with the preferred listening levels of individuals with acquired hearing impairment, along with these the self-reported benefits of these fitting condition were also assessed. 30 participants with different degrees (from mild to severe) and different configurations of hearing loss participated in their present study. They found that regardless of the individual variability with respect to the degree as well as configuration of hearing loss, the adult DSL v5.0a targets approximated the preferred listening level strongly, especially for speech at conversational levels. The relation between PLL and target listening level did not vary significantly.

Achaiah (2011) compared the outcomes of preferred gain over the prescribed gain settings of NAL – NL1 & DSL [i/o], among the experienced hearing aid users under NAL-NL 1 and DSL [i/o]. Ten participants with sensorineural hearing loss participated in their current study. They found that overall gain is found to be higher for preferred conditions compared to NAL-NL 1 and DSL [i/o]. on comparison with

REIG scores they found that there was a significant difference between preferred and the prescribed targets. When speech identification scores were assessed, they found there were a significant difference between preferred and DSL [i/o], and no difference between preferred and NAL-NL 1. They concluded that higher gain was preferred by the hearing impaired individuals over the prescribed gain especially at mid- and high-frequencies and suggest the importance of fine tuning of hearing aids based on the individual's preference.

2.5 Comparison between insertion gain measurement and PLL

As stated earlier, Insertion gain measurements is found to be a key measurement to check if the gain prescribed in the hearing aid is accurate and provides a basic idea about the necessary changes that have to be made to achieve the target. Swan and Gatehouse (1995) found that only after the necessary changes 85% of the hearing aid users in their study were found to achieve a satisfactory gain. Whereas 57% of the hearing aid users failed to fall within 10 dB of the target gain at one or more frequencies between 250Hz to 3000Hz. Dillon (2007) from a series of studies carried out by Keisder et al (2001, 2005, 2006, 2007) found that preferred gain with respect to NAL-NL1 at 65 dB input level was appropriate only for 49% of the hearing aid users; for 46% the gain prescribed by the NAL-NL1 was 3 dB more than it was required. Keisder & Grant (2001) found that for experienced hearing aid users, NAL-NL1 normally overestimated the overall gain of about 3 dB for a 65 dB SPL input level.

Dillon (2003) checked whether hearing aid users prefer less overall gain than prescribed by the NAL-NL1 in their real life environments. They compared the average preferred gain settings to that of the gain settings of NAL-NL1 prescription for a 65dBSPL speech input level. They found that individuals preferred 0.70 dB, 0.53 dB and 1.5 dB less gain at low and high frequencies than the prescribed gain. In a study done by Leijon, Likvist, Ringdahl and Israelsson (1990) compared the insertion gain measures between the gain settings as preferred by the hearing aid user in their daily life situation and the prescribed gain settings with respect to the NAL prescriptive formulae. They found that most of the subjects clearly preferred a lesser insertion gain in 1 to 2 KHz region than prescribed by the NAL formulae. The difference between the recommended and prescribed gain were statistically significant.

Hence, from the above studies it is clear that there is a discrepancy between the prescribed gain and the preferred gain settings which do not meet the need of an individual. This discrepancy among the preferred gain and prescribed gain found to shed its effect on the speech perception in an individual. The present study aimed to evaluate the difference in insertion gain and difference in speech identification scores between first fit, preferred settings and real ear insertion gain settings using NAL NL-1 prescriptive formula in individuals with hearing impairment.

CHAPTER 3

METHOD

The present study aimed to compare the REIG in SPL across the first fit condition (where, the hearing aid was programmed according to the NAL-NL1 prescriptive procedure with no fine tuning from the initial fit), matched to the target in REM system (where fine tuning was made to match the REM system's REIG curve to the target gain as prescribed by NAL-NL1 equation in REM) and preferred condition (which the person chooses or prefers for listening to hearing aid amplified speech and routine hearing aid evaluation) with NAL–NL1 prescriptive formulae and the speech identification scores with different gain settings across three different input levels (45 dB, 65 dB and 80 dB SPL). The study used experimental within subject design in order to investigate the objectives of the study. The method consisted of the following steps:

Step 1: Selection of participants.

Step 2: Hearing aid programming and routine hearing aid evaluation.

Step 3:Experiment to measure the REIG with NAL – NL1 prescriptive formulae in the three different gain settings across various input levels (45, 65 and 80 dB SPL).

Step 4: Measurement of speech identification scores between the different gain settings at 45, 65 and 80 dB SPL.

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3.1 Selection of participants

The present study included 15 ears of eight participants with post-lingual mild to moderate flat sensorineural hearing impairment with an age range of 33-53 years (Mean Age = 44.5, SD = 5.7; Males = 7 and Females = 1) were selected for the present study. All the participants fulfilled the following criteria:

3.1.1 Inclusion criteria

- Participants with unilateral/bilateral flat sensorineural hearing loss were selected for the study. The configuration was considered flat if the difference was not more than 10 dB HL at every octave from 250 Hz to 8000 Hz (Kennedy, Levitt, Neuman, & Weiss, 1998).
- Speech identification scores was not less than 70%,
- ‘A’ or ‘As’ type of tympanogram with acoustic reflex thresholds which were appropriate to the degree of hearing loss at 500 Hz to 4000 Hz,
- All the participants had past experience with a WDRC digital hearing aid with an option for DNR and directionality in the test ear with the minimum of 1 year, and
- All of them had Kannada language as their mother tongue.

Audiological data of the participants, which includes degree of hearing loss, SIS, hearing aid being used and the duration of the hearing aid use is provided in the table 3.1

Table 3.1

Demographic and audiological data of the participants in the present study

S.no	Age/ Gender	PTA		SIS (%)		Tymp	Reflex	Hearing aid model	Hg.aid Exp (years)
		R	L	R	L				
1	38/M	55	--	72	--	A	NR	Una sp	2
2	47/M	42.5	48.7	80	76	A	P	Ally-286	1.7
3	44/M	51.2	52.5	72	76	A	NR	BO-295	1.3
4	48/M	52.5	57.5	76	72	A	NR	HIT p	2
5	35/M	51.7	55	80	76	A	NR	Get p	1.7
6	53/F	52.5	53.7	80	72	A	NR	Get p	2.1
7	48/M	42.5	48.7	76	72	A	NR	Get p	2
8	44/M	48.7	45	72	76	A	P	Riva 1p	2

Note. NR – No Reflex, P – Present, -- details were not obtained

3.1.2 Exclusion criteria

- Participants with otologic disorders, neurological involvement and psychological related problems were excluded from the study. Case history was used to confirm the details on the above aspects.

3.2 Instrument Used

- A dual channel diagnostic audiometer, GSI-61, was calibrated and was used for routine audiological evaluation as well as for the actual experiment. The tests were carried out using this audiometer with TDH 39 supra aural head phones which was housed in MX-41 AR cushion and Radio Ear B-71 bone vibrator for routine audiological evaluation
- Two loud speakers located at 1 meter distance at 45° angle for routine evaluation and for the actual experiment.
- GSI-Tympstar middle ear analyzer was used to assess the functioning of the middle ear, tympanometry and acoustic reflex
- Their own digital WDRC hearing aid were used for the experiments
- Fonix 8000 Hearing aid analyser was used to assess the insertion gain measurements
- The personal computer with windows 10 configuration was used to program the hearing aids which were connected to Hi-PRO (an interface) with the help of NOAH-4.6 software. Suitable cable for programming along with the specific program software given by that particular hearing aid company had been used to program the hearing aid.
- A personal laptop windows 10 configuration was connected to the audiometer auxiliary input to present the target stimuli for speech perception.

3.3 Test Environment

- A sound treated air conditioned double room set-up was used to administer all the above mentioned tests. The noise level in the testing room was maintained within the permissible limits (ANSI, 1999).

3.4 Stimuli

- SRT testing was carried out using the Kannada spondee word lists developed by the Department of Audiology, All India Institute of Speech and Hearing, Mysore.
- SIS was obtained using the PB word lists (4 lists of 25 words) which were developed in Kannada language by Yathiraj and Vijayalakshmi (2005) for routine hearing evaluation. For the actual experiments, word lists developed by Manjula, Antony, Kumar and Geetha, (2015) was used. This test has 21 lists of 25 phonemically balanced words.
- Stimuli used for the real ear measurements was the stimuli developed by the European Hearing Instrument Manufacturers Association (EHIMA) known as ISTS that closely resembles properties of natural speech.

3.5 Procedure

3.5.1 Procedure for Routine audiological evaluation

- Routine audiological evaluation included Pure-tone Audiometry, Speech audiometry and Immittance evaluation. Audiometric thresholds of both air conduction and bone conduction was estimated from 250 Hz to 8 kHz and from 250 Hz to 4 kHz respectively, using modified Hughson and Westlake procedure (Carhart and Jerger, 1959). Average of air conduction thresholds at 500 Hz, 1 kHz, 2 kHz and 4 kHz will be used to arrive at the pure tone average.

- Speech Identification Scores (SIS) were obtained at 40 dB SL (re: SRT) using the PB word lists which was developed in Kannada language by Yathiraj and Vijayalakshmi (2005). LDL for speech was also obtained. SIS was used to correlate with the obtained PTA using Kannada paired words.

- Immittance Evaluation included Tympanometry and Acoustic reflex. These measurements had been carried out using GSI-Tympstar middle ear analyzer instrument using the normal standard procedures. Based on the results of the above tests, participants who fulfilled the selection criteria underwent further evaluations.

3.5.2 Hearing aid programming and routine hearing aid evaluation

- The participants were initially fitted with their own digital BTE hearing aid, using the computer with the NOAH-4.6 software which was connected to NOAH AIR LINK.
- Hearing aid was programmed based on NAL–NL1 Prescriptive formula using the audiometric thresholds of the individual and First fit was applied. These settings were used for the ‘First Fit’ condition in the experiments
- The gain settings of the hearing was modified till the participants could identify the ling’s six sounds that was presented at a distance of 1 meter. These settings were used for ‘preferred’ gain setting.
- The default compression settings were kept constant. Noise reduction strategies had been activated for all the participants.

- A routine hearing aid evaluation using the audiometer was carried out by asking five questions and finding out SIS at 40 dB HL.

3.5.3 Experiment to measure the REIG

Participants were seated in the sound-treated room. Otoscopy examination was carried out prior to the REM to ensure all participants are free from cerumen or wax. Individual's audiogram was loaded in to the Fonix 8000 system. Real ear SPL measurement option was selected in order to find the SPL in the ear canal. Participants were made to sit at 45 (degree) azimuths with respect to the loudspeaker and at a distance of 12 inches from the loud speaker. The probe microphone of the Fonix 8000 system was inserted into the ear canal of the participant using the 'composite' method (Hawkins and Mueller, 1992). The marker was used to mark the appropriate depth that can be inserted inside the participant's ear canal. The participants were instructed to maintain the same position during the recording and they were asked to inform in case of any discomfort during the procedure. Levelling procedure was carried out after the probe tube was inserted into individual's ear canal. REM measurements were recorded with the default settings available within the instrument**..** The stimulus used was ISTS.

Real ear unaided response (REUR) was measured without the hearing aid using FONIX 8000 real ear measurement module at three different input levels (45 dB, 65 dB and 80 dB SPL). The stimulus was presented and the output was represented in the form of a graph on-screen. The input signal was stopped once the REUR graph was stabilized for more than 10 seconds. Later, these graph measurements were converted to REUR scores and tabulated.

Following the Real ear unaided response, his/her own hearing aid was switched on. Real ear measures with his/her hearing aid switched on (REAR) were performed for the individual's with NAL-NL 1 gain settings with the help of FONIX 8000 hearing aid analyzer. The stimulus was presented and the output was represented in the form of a graph on-screen. The input signal was stopped once the REAR graph was stabilized for more than 10 seconds. Later, these graph measurements were converted to REAR scores and tabulated.

Real Ear Insertion Gain (REIG) was calculated as the difference between real ear aided response and real ear unaided response or REIG = (REAR – REUR). The gain at three input levels (45 dB, 65 dB and 80 dB) was noted.

The above measurements were carried out at three different conditions. They are explained below:

1. **At first fit gain setting**

   For every hearing aid user, the hearing aid was programmed according to the NAL-NL1 prescriptive procedure. No fine tuning was done from the initial fit as prescribed from the NAL- NL1 formula at this setting.

2. At matched to target gain in REM system setting

The hearing aid was connected to the programming software of the hearing aid through the NOAH link module while performing the real ear measurements of an individual. In the real ear measurement system REIG curve was matched to the target gain prescribed by NAL-NL1 equation by altering the gain through programming system simultaneously. Thus, the gain of each channel or frequency shaping for the hearing aid was adjusted in real time by the clinician to best match the real ear target at all frequencies. The gain settings across frequency, frequency shaping and compression parameters were kept in records.

3. At prescribed gain setting

The hearing aid fitting for the individuals were fine-tuned through the frequency shaping option of the NOAH 4.6 program to determine the preferred gain settings. This fine tuning procedures was performed following standard audiologic protocol. Questions were asked on one to one basis and ling's six sound test was performed. The low cut and high cut gains were then manipulated depending on subject's response. If it sounded soft, gain for the soft level inputs was increased for the soft input levels and if it sounded louder high level gains or overall gain was reduced. Adjustments were carried out until the overall quality of speech was judged to be comfortable and acceptable. As a final point participant's were allowed for a one to one conversation.

3.5.4 Measurement of speech identification scores between REIG and preferred gain measures

Speech Identification Score (SIS) was assessed in Kannada language for a list of 25 phonetically balanced (PB) words from the test material developed by Manjula, Antony, Kumar and Geetha, (2015). Participants were seated in the sound-treated room. Stimuli were presented through a loudspeaker placed at 45 degree azimuth and at distance of 1 meter. The word lists were presented randomly and no list was repeated during the procedure for an individual. The participants were instructed to repeat the words. The mode of scoring was live by the experimenter. It was scored out of 25 words and by finding out the percentage for the correct responses. A score of ‘1’ was assigned for every correct response and ‘0’ for every incorrect response.

The speech identification scores were measured using single blinded procedure where the participants were not aware of the condition at which the testing was being done. The speech identification scores were measured in the three conditions, First-Fit setting, Matched target setting and at preferred setting.

3.6 Statistical analysis

The following data were subjected to statistical analysis using the SPSS (Statistical package for social science) software version 21 to compare the gain and SIS in different conditions. Shapiro Wilk’s test was carried out initially to find out whether the collected data follow a normal distribution. Later, Friedman test and Wilcoxon signed rank tests were carried out.

CHAPTER 4

RESULTS

The current study aimed to evaluate the differences in real ear gain and differences in speech identification scores between three different gain settings. They were First-Fit gain settings (where, the hearing aid was programmed according to the NAL-NL1 prescriptive procedure with no fine tuning from the initial fit), matched to target gain setting (where fine tuning was made to match the REIG curve to the target gain as prescribed by NAL NL1 equation) and preferred gain (which the person preferred for listening to hearing aid amplified speech during routine hearing aid evaluation) with NAL NL1 prescriptive formulae. The results are presented under the following headings:

4.1 Comparison of REIG between three gain settings, and

4.2 Comparison of speech identification scores (SIS) between three gain settings.

4.1 Comparison of REIG between three gain settings with NAL-NL1 prescriptive formulae

Insertion gain measurements obtained across three different gain settings as mentioned above, at three different input levels between 250 Hz and 6000 Hz at octaves and mid-octaves were tabulated in SPSS version 21. The mean, median and SD of the same are given in Table 4.1.

Table 4.1

Mean, Median and SD of Insertion gain in all the conditions across different input levels and frequencies (N = 15)

Frequency ⇨		250		500		750		1000		1500		2000		3000		4000		6000	
Input level ⇩	Condition	MEAN (SD)	MED	MEAN (SD)	MED	MEAN (SD)	MED	MEAN (SD)	MED	MEAN (SD)	MED	MEAN (SD)	MED	MEAN (SD)	MED	MEAN (SD)	MED	MEAN (SD)	MED
45	FF	9.78 (4.52)	11.1	10.44 (4.33)	11.6	14.04 (7.64)	15.8	17.32 (5.74)	17.7	14.99 (4.38)	16.00	15.98 (3.99)	16.6	12.10 (2.53)	11.3	12.44 (4.89)	12.4	23.29 (3.49)	23.9
	MAT	19.94 (8.39)	22.4	20.16 (4.46)	20.6	32.32 (6.7)	33.3	32.10 (5.71)	32.7	29.54 (4.35)	29.6	38.15 (7.61)	36.8	25.11 (5.02)	23.6	28.04 (8.19)	27.1	31.28 (6.83)	30.4
	PFD	14.49 (8.09)	18.6	19.66 (9.34)	22.9	29.6 (10.0)	33.8	33.44 (8.99)	35.9	27.68 (7.10)	29.5	31.36 (6.02)	33.3	22.75 (5.55)	24.8	25.80 (5.96)	25.1	26.20 (4.78)	28.0
65	FF	7.34 (3.72)	7.3	9.30 (3.17)	10.3	16.99 (5.19)	18.0	16.48 (5.20)	15.5	15.22 (4.99)	16.4	17.12 (4.08)	18.3	8.37 (4.54)	8.5	9.34 (3.48)	9.2	10.15 (5.57)	9.2
	MAT	10.80 (3.18)	12.1	14.32 (3.61)	14.7	25.86 (5.52)	27.4	26.34 (4.74)	27.2	23.88 (5.35)	25.1	25.48 (3.65)	25.6	22.78 (4.14)	24.1	19.69 (6.38)	20.4	15.77 (6.77)	16.5
	PFD	9.60 (3.70)	10.6	13.16 (5.49)	15.3	21.66 (7.99)	24.3	26.36 (8.69)	24.7	22.84 (9.87)	27.5	25.54 (6.06)	25.6	17.60 (4.82)	19.4	21.04 (4.10)	21.1	16.62 (5.49)	18.5
80	FF	4.21 (4.6)	3.6	1.67 (2.82)	2.1	6.99 (3.75)	7.1	12.09 (14.55)	9.6	5.31 (4.97)	4.97	6.75 (6.04)	7.3	1.97 (5.03)	5.03	5.3 (3.3)	5.6	7.05 (6.39)	6.9
	MAT	6.06 (2.39)	6.2	7.7 (3.74)	8.2	15.58 (2.82)	14.8	15.95 (4.59)	16.5	16.28 (4.89)	16.9	14.23 (4.48)	3.5	8.15 (4.14)	4.14	14.07 (3.58)	14.5	12.19 (5.42)	12.0
	PFD	4.73 (2.89)	3.6	6.21 (3.58)	6.2	14.45 (6.5)	14.4	14.77 (7.31)	15.2	14.25 (9.2)	17.1	13.41 (7.16)	12.1	7.13 (7.41)	7.1	11.07 (6.46)	12.3	7.81 (3.72)	7.9

Note. FF – First Fit; MAT – Matched Target gain in REM; PFD – Preferred gain.

From the Table 4.1 it can be observed that the insertion gain differed across three different gain settings at different input levels. The mean of the insertion gain were found to be the highest for matched to target gain in REM condition followed by the preferred gain and the first fit conditions at all the three intensity levels. Statistical analysis was performed to see if the differences were statistically significant. As a first step of statistics, Shapiro-Wilk's test was performed in order to examine if the data collected followed normal distribution. REIG in dB SPL between the First Fit, matched and the preferred condition were subjected to Shapiro-Wilk's normality test. The results showed that majority of the data did not follow normal distribution and hence, non-parametric statistical analyses were performed.

Friedman test was done to compare insertion gain across different conditions at three different levels at frequencies between 250 Hz and 6 kHz. The results of this are presented in Table 4.2. It can be seen from the Table 4.2 that there was a significant difference ($p < 0.05$ and $p < 0.01$) among different conditions at 45 dB and 65 dB SPL input levels for all the frequencies. Whereas at 80 dB input level, there was a significant difference among all the conditions at all frequencies except 250Hz and 1000 Hz frequencies ($p > 0.05$).

Table 4.2

Results of Friedman test for Insertion gain across different gain settings at different intensities (N =15)

Frequency ⇨ / Input level ⇩	χ^2								
	250	500	750	1000	1500	2000	3000	4000	6000
45	19.600**	19.600**	20.133**	20.800**	19.733**	30.000**	21.733**	19.600**	20.933**
65	14.475**	19.897**	22.068**	14.400**	10.133*	17.186**	22.533**	16.933**	12.400**
80	7.600	15.600**	17.729**	7.600	16.933**	11.200*	12.133*	17.733**	14.533**

Note: ***p* < 0.01; **p* < 0.05.

In order to find out which of the conditions differed from each other, Wilcoxon signed rank test was further done for the conditions where there was a statistical significant difference. The results of this are presented in Table 4.3.

Table 4.3

Comparison of insertion gain across different gain settings at different intensities using Wilcoxon signed rank test (N=15)

Input level	Condition	Z value: Frequency 250	500	750	1000	1500	2000	3000	4000	6000
45	FF and MAT	-3.353**	-3.415**	-3.408**	-3.411**	-3.411**	-3.408**	-3.411**	-3.409**	-3.411**
	FF and PFD	-2.842*	-3.183**	-3.241**	-3.298**	-3.241**	-3.409**	-3.354**	-3.353**	-2.445**
	MAT and PFD	-3.358**	-.227	-1.820	-1.024	-.853	-3.415**	-1.679	-.597	-2.959*
65	FF and MAT	-3.411**	-3.412**	-3.412**	-3.409**	-3.410**	-3.413**	-3.409**	-3.299**	-2.275
	FF and PFD	-2.500	-2.961*	-2.546	-2.900*	-2.388	-3.239**	-2.956*	-3.352**	-2.844
	MAT and PFD	-2.043	-1.037	-3.187**	-0.285	-0.057	-0.566	-3.242**	-0.057	-0.341
80	FF and MAT	--	-2.900*	-3.409**	--	-3.409**	-3.182**	-3.040*	-3.296**	-2.587
	FF and PFD	--	-2.618*	-3.069*	--	-2.900*	-2.841*	-2.729*	-2.614*	-0.682
	MAT and PFD	--	-1.367	-0.220	--	-1.081	-0.739	-0.512	-1.535	-3.331**

Note. ** p<0.01 and* p < 0.05; FF- First Fit; MAT- Matched to target gain in REM; PFD – Preferred gain; -- No significant difference in Friedman test.

The Table 4.3 shows that at all input levels, there was a significantly higher insertion gain values obtained in the matched to target gain in REM system condition when compared to First Fit. The results also revealed a significant higher insertion gain with preferred gain settings than at first fit settings. However, there was no significant difference between insertion gains obtained with matched to target gain in REM system and preferred gain at most frequencies.

4.2 Comparison of speech identification scores (SIS) between three gain settings

Speech identification scores were obtained at three different conditions (preferred gain, first fit and the matched target gain) at three different input levels. The mean, median and SD of SIS for all the conditions are given in Table 4.4

Table 4.4

Mean Median and SD of speech identification scores across different conditions at different input levels (N=15).

Intensity Level (dB SPL)	Speech Identification Scores			
	Conditions	Mean	Median	SD
45	Unaided	5.60	5.00	3.97
	First fit	13.66	13.00	1.91
	Matched target	15.33	15.00	3.22
	Preferred	17.60	18.00	1.99
65	Unaided	12.20	12.00	3.07
	First fit	16.53	17.00	3.75
	Matched target	20.20	20.00	1.08
	Preferred	20.80	21.00	2.04
80	Unaided	17.00	17.00	1.69
	First fit	18.93	18.00	1.57
	Matched target	21.40	21.00	1.12
	Preferred	22.40	22.00	1.40

Note. Maximum possible score for SIS = 25.

It can be observed from the Table 4.4 that the SIS differed across the three different gain settings at different input levels. The mean and SD of the speech identification measures were found to be the highest for preferred gain condition followed by the matched to target gain in REM system and the first fit gain condition in the descending order, at all the three intensity levels. Statistical analysis was performed to see if the differences were statistically significant. Shapiro-Wilk's test was performed in order to examine if the data collected followed normal distribution. The results showed that majority of the data did not follow normal distribution and hence, non-parametric statistical analyses were performed.

Friedman test was done to compare SIS across different conditions. The results showed that there was a significant difference ($p<0.01$) among different conditions at 45 dB SPL [$\chi^2 = 39.790$, $p = 0.000$] and 65 dB SPL [χ 2 = 39.923, p = 0.000] and 80 dB SPL [$\chi^2 = 42.540$, $p = 0.000$] input levels.

In order to find out which of the conditions differed from each other, Wilcoxon signed rank test was done. The results of this are presented in Table 4.5.

Table 4.5

Comparison of speech identification scores across different conditions at different intensities using Wilcoxon signed rank (N =15)

Intensity Level (dB SPL)	Conditions	/Z/	*p*
45	FF and MAT	-2.450	0.014
	FF and PFD	-3.429	0.001
	MAT and PFD	-3.081	0.002
65	FF and MAT	-3.210	0.001
	FF and PFD	-3.426	0.001
	MAT and PFD	-1.244	0.214
80	FF and MAT	-3.443	0.001
	FF and PFD	-3.472	0.001
	MAT and PFD	-2.519	0.012

Note. FF- First Fit; MAT- Matched to target gain in REM; PFD – Preferred gain.

A significant difference was observed between the preferred condition and the first fit condition between matched to target gain in REM system condition and first fit condition and also between the matched target condition and the preferred condition at all the intensity levels measured. The significance of difference was the highest between the first fit and matched condition followed by the first fit and preferred conditions in the descending order.

To summarize the above results, among the three conditions (first fit, matched to target in REM system and preferred conditions) matched to target condition was found to give more insertion gain compared to the preferred condition and first fit condition. However, preferred condition was found to be better for speech perception in an individual compared to first fit condition and matched to target in REM system conditions.

CHAPTER 5

DISCUSSION

The objectives of the study were to compare insertion gain and SIS measured across three different hearing aid gain settings at three different input levels. The results of insertion gain and SIS are discussed below.

5.1. Comparison of REIG between three gain settings

Real ear insertion gain was found to be significantly higher for the matched target condition followed by the preferred condition and the first fit condition in the descending order. These results are consistent with the study done by Achaiah (2011). Achaiah compared insertion gain between preferred and first fit gain settings only. It was reported that an average individual preferred a 10 dB higher gain compared to NAL-NL 1 prescriptive formula. The reason attributed to this was possibly due to the frequency importance function (FIF) used to construct the prescriptive equation. The language and type of speech material used for arriving at FIF have been proved to affect FIF (Pavlovic, 1994). For NAL-NL1 equation, English material has been used. There are evidences for structural differences between Indian and English languages. Once such evidence is given by Narne et al. (2016) where they reported differences at many frequency regions in FIF between Malayalam and English.

In the present study, insertion gain of the matched to target gain resulted in the highest measured insertion gain values, that is, the values obtained through hearing aid programming software were much lower than that of real ear insertion gain after matching to target gain in REM system. Contrary to the present study, Aarts and Caffee (2005) found that there was an over estimation of individually obtained real ear measurement values obtained through hearing aid programming software under the simulated condition. Similarly insertion gain measurements obtained through the HA programming software was way higher than the REIG measurements obtained through the probe microphone measurements as reported by Campos et al (2011).

5.2. Comparison of speech identification scores (SIS) between three gain setting

Speech identification scores were found to be significantly higher for the preferred condition followed by the matched target condition and the first fit condition. Achaiah (2011) also found that speech recognition scores at preferred gain settings were higher than the first fit settings. These results are in correlation with the insertion gain results.

However, when SIS obtained at gain settings after REM target was matched was lower than that of preferred gain settings. That is, though the real ear insertion gain was more in that condition, the SIS was lesser.

Turner and Cunnings (1999) also provided the same evidence that maximizing the amount of audibility was not always the beneficial strategy for patients with SNHL. REIG at preferred gain was lesser than at the matched to target in REM system condition at all input levels and preferred gain setting was sufficient enough to bring a significant change in speech perception. Thus, increasing the amount of amplified speech does not increase speech intelligibility in an individual.

Real ear insertion gain at preferred listening level is higher than the first fit listening level. Hence, fine-tuning the hearing aid to reach the preferred setting is important. Though the real insertion gain is higher when matched with target gain in REM, it may not result in favorable SIS. Hence, during hearing aid fitting, if real ear insertion gain measures are used, it’s always preferred to adjust the gain based on listeners’ preference as well.

CHAPTER 6

SUMMARY AND CONCLUSION

Fine-tuning of hearing aids of individuals with hearing impairment has an important role particularly in speech perception. In many hearing aid protocols, especially pediatric protocols include insertion gain as the main hearing aid fitting procedure. While the difference between the target gain and prescribed gain is well documented, the difference between insertion gain that is matched to the target curve of the prescriptive equation and preferred gain is not well understood and this disagreement between the preferred gains over the insertion gain may have its effect on speech perception also.

Hence, the aim of the present study was to evaluate the difference in insertion gain and difference in speech identification scores between first fit as prescribed by the NAL NL-1 prescriptive formula, preferred gain setting by an individual and the gain setting that matched to the target gain provided by NAL NL-1 prescriptive formula in REM system. Fifteen ears of eight participants with post-lingual mild to moderate flat sensorineural hearing impairment with an age range of 35-53 years had been included in the study. REIG was calculated at three input levels (45 dB, 65 dB and 80 dB) and at three different gain settings as mentioned above. Speech identification scores was measured using phonetically balanced (PB) words from the test material developed by Manjula et al., (2015) at three different conditions across the three different input levels.

Results showed that Insertion gain was found to be significantly higher for matched target condition ($p<0.01$; $p<0.05$) followed by the preferred gain and the first fit conditions at all the three intensity levels. However, speech identification scores were found to be significantly higher for preferred gain condition (p<0.01) followed by the matched target gain condition and the first fit gain condition.

It can be inferred from the results of the present study that the individuals preferred lesser insertion gain values than those prescribed by the NAL NL-1 prescriptive formulae in real ear. Preferred condition was found to be better for speech perception in an individual compared to first fit condition and matched to target conditions. Hence, it can be concluded that for the NAL-NL 1 prescriptive formula, the preferred gain settings were positively influencing the speech perception in an individual at different input levels (45, 65 and 80dB SPL) and should be relied upon more than REIG matched to target in REM system.

However, the results may be specific to the stimulus conditions and stimulus type used for the measurement of REIG. Hence, similar studies are required to support the results of the present study in noise conditions.

6.1 Clinical Implications

- The results of the present study provide an evidence for the benefit provided by the preferred gain over the matched to target gain in REM system and the first fit gain condition by the NAL NL-1 prescriptive formula.
- These results provide guidelines for the protocol that can be used for programming the hearing aid and the routine hearing aid evaluation.

- Importance of follow up and fine tuning can be emphasized for greater benefit and the information on this fine tuning will help audiologist to enhance their knowledge on fine tuning changes required for an individual.

6.2 Future Directions

- Further studies can be done using noise for speech perception assessments.
- Studies with different types of hearing loss, and different degrees of hearing loss can help an audiologist to find the pattern of changes that can be incorporated during the initial fit or during the change in programming over time.

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