Hearing aid for tinnitus management: A comparison study of amplification strategies on audibility of tinnitus

Vandana, B.

Register No. 14AUD026

This Dissertation is submitted as part fulfillment

for the Degree of Master of Science in Audiology

University of Mysore, Mysuru

MAY, 2016

Certificate

This is to certify that this Masters dissertation entitled '**Hearing aid for tinnitus management: A comparison study of amplification strategies on audibility of tinnitus'** is a bonafide work in part fulfillment for the degree of Master of Science (Audiology) of the student with Registration Number 14AUD026. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other Universities for the award of any Diploma or Degree.

Mysuru,

May, 2016

Prof. S.R. Savithri

Director

All India Institute of Speech and Hearing

Manasangangothri,

Mysore-570006

Certificate

This is to certify that this Masters dissertation entitled '**Hearing aid for tinnitus management: A comparison study of amplification strategies on audibility of tinnitus'** is a bonafide work in part fulfillment for the degree of Master of Science (Audiology) of the student with Registration Number 14AUD026. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other Universities for the award of any Diploma or Degree.

Mysuru

May, 2016

Dr. Hemanth.N

Guide

Lecturer in Audiology

AIISH, Manasagangothri, Mysuru-570006

Declaration

This Masters dissertation entitled **'Hearing aid for tinnitus management: A comparison study of amplification strategies on audibility of tinnitus'** it is the result of my own study and has not been submitted to any other university for the award of any other Diploma or Degree.

Mysuru **Registration No. 14AUD026**

May, 2016

Dedicated to my

loving parents

and my Brother

Acknowledgement

I would like to extend sincere gratitude to my guide Dr. Hemanth N for his valuable guidance, suggestions and moral support in every stage of the study. Sir! Thank you for being patient, sweet, student friendly and showing directions whenever needed.

I would like to thank Dr. S R Savithri, Director of All India Institute of Speech and Hearing for permitting me to carry out this study.

I render my sincere thanks to Dr. Sandeep M, Head of Department of Audiology for having permitted me to use the department facilities for the study as per the convenience.

I would like to thank all my participants of the study, for their kind co-operation throughout the study without them this would have been incomplete.

I would like to acknowledge all faculty departments of Audiology, AIISH.

A special thanks to Sindhu for her support throughout the study

Last but not the least I would like to thank all my B.sc and M.sc classmates, juniors and passed out seniors.

Abstract

Objective: The present study was taken up to investigate the best amplification strategy that provides tinnitus relief in a quiet environment in patients with sensorineural hearing loss who have bothersome tinnitus. The following objectives were formulated a) To measure Minimal Masking Level (MML) on tinnitus suppression b) to find the relation between tinnitus pitch and gain at tinnitus pitch in each strategy (DSL i/o v -5 at compression threshold of 30 dBSPL, DSL i/o v-5 at compression threshold of 50 dBSPL, NAL-NL1 at compression threshold of 30 dBSPL and NAL-NL1 at compression threshold of 50 dBSPL) and b) to determine the best amplification strategy that gives relief from tinnitus using paired comparison method.

Method: A one shot posttest only and randomized repeated measures research design was utilized. Fourteen participants with unilateral and bilateral tone like tinnitus participated in the study whose age ranged from 20 to 80 years. These participants were made three grouped based on the scores of Tinnitus Handicap Inventory (THI). From each participant, MML on tinnitus suppression and the best program selected among four strategies provided tinnitus relief were measured.

Results: In each group of participants , MML on tinnitus suppression was descriptively analysed. A spearman's correlation revealed no significant relation between MML at tinnitus pitch and gain at tinnitus pitch. Each group of participants showed no preference among four strategies in hearing aid.

Conclusion: Other than prescriptive formula and compression threshold, a few features in hearing aid (open fit, omnidirectional, deactivated DNR and optimizing

gain at tinnitus pitch) have an effect in providing relief from tinnitus. However, a caution must be taken in fitting hearing aid to tackle both hearing loss and tinnitus by effectively using the options available in aid. This is because in amplifying the ambient noise from hearing aid there would be a high chance of rejecting it because of annoyance experience from amplifying ambient noise. Thus, to avoid annoyance during conversation, a separate program can be set in hearing aid to obtain relief from tinnitus especially in quiet environment.

Table of contents

List of Tables

List of Figures

Chapter 1

Introduction

Common term of tinnitus is known as 'Ringing in the ears' is a perception of sound without any external stimulus (Norena and Eggermont, 2003). Most patients describes tinnitus quality as ringing (38%), buzzing (11%), Crickets(9%) and humming (5%) as reported by Henry, Dennis and Schehter (2005). Tinnitus is majorly associated with either unilateral or bilateral hearing loss (Kim et al, 2015). Assessment of tinnitus pitch and loudness is a preliminary measures in which tinnitus patient necessitates in initiating with any rehabilitation program. Minimum Making Level (MML) is one such assessment method uses masking method (Feldmann, 1971) to assess tinnitus pitch and loudness. In MML an intensity of narrowband noise required to mask tinnitus was found across frequencies. Wegal and Lane (1924) observed lowest masking level required at a frequency close to tinnitus pitch.

Tinnitus is more common in individuals with hearing loss. In one year of period prevalence study on tinnitus by Thirunavukkarasu and Geetha (2015) reported in 97.5 % of individuals having tinnitus had hearing loss. In addition, older adults with an age 60 years and above experienced tinnitus than compared to other age groups. Further, 23.7% of individuals with tinnitus had moderate to moderately severe degree of hearing loss.

Hearing aids are one of the management options used since 1940s till date, as it suppresses tinnitus. Hearing aid causes relief from tinnitus by many ways including: 1) masking the tinnitus from ambient noise of the device 2) Reduces the audibility of tinnitus by paying less attention and 3) improves quality of life and or secondary effect of tinnitus by reducing anxiety, stress , and depression (Kochkin & Tyler , 2008). Surr, Montgomery and Mueller (1985) reported that approximately 50% of tinnitus patients achieved some relief from hearing aid. In yet another study by Surr , Kolb , Cord and Garrus (1999) found an average of 10% improvement in tinnitus handicap over 6 weeks following the fitting of hearing aid users. In contrast, Melin, Scott, Lindberg and Lyttkens (1987) said that hearing aid alone will not decrease the tinnitus and associated problem if any. They reported that likelihood of reduction in tinnitus depends on careful selection of hearing aid characteristics, with the intention of reducing tinnitus audibility. Some of the options in hearing aid can be changed for tinnitus management which includes; using open fit rather than fitting a hearing aid with ear mould (Parazzini, Del Bo, Jastreboff,, Tagnola and Ravazzani , 2011) ,low compression thresholds(Wise, 2003) switching off the noise reduction circuit (Ricketts and Mueller, 1999), sensitivity of microphone turned on to pick up the signal in all direction (Ricketts and Mueller , 1999) and finally prescribing the gain using DSL i/o for ameliorating the effect of hearing loss on perception of speech (Searchfield, 2010).

In open fit of hearing aid, environmental sound can easily take entry into the ear canal there by tinnitus sound is partly reduced (Sheldrake, Coles & Foster , 1995). However, blocking the ear canal with molds can produce occlusion effect there by internal physiological noise enhances and at the same time tinnitus sound also increases. Thus, hearing aid fitted with dome is more effective in suppressing tinnitus than compared to ear mould. Wise (2003) conducted study by changing the compression threshold in hearing aid on audibility of tinnitus. It was hypothesized that compressor in hearing aid activated by input signal produce the ambient noise which in turn suppresses tinnitus. The results revealed that low compression kneepoint is effective in reducing the audibility of tinnitus as it produces circuitry noise while amplifying low input signal to audible level. Thus, in wide dynamic range compression with low compression kneepoints of around 20-45 dB SPL was recommended for suppressing tinnitus

Other options in hearing aids such as changing the sensitivity of microphone and activation of noise reduction circuit were used to understand speech against background noise. However, these options were disabled in hearing aid in individuals having hearing loss with bothersome tinnitus. Ricketts and Mueller (1999) conducted study by deactivating the noise reduction algorithm and changing sensitivity of microphone on tinnitus suppression. It was found that in those participants who wore hearing aid with settings switching off of DNR and omnidirectional microphone benefitted maximally on tinnitus relief. This is because microphone captures signals from all direction. In addition, hearing aid

allocates gain towards hearing loss in each band does not reduces irrespective of temporal change by noise and speech. The resultant amplified sound comprised of both ambient noise and speech signals. Thus, digital noise reduction algorithm should be turned off and microphone should be sensitive in all direction to suppress tinnitus effectively. Further, prescriptive procedures for hearing aid amplification such as NAL-NL1 (Dillion, 1999) and DSL(i/o) (Cornelisse, Seewald & Jamieson,1995) have been used to provide appropriate amount of amplification based on hearing threshold of individuals to improve speech perception scores. It was noted that DSL i/o gives more gain at low frequency (Cornelisse, Seewald & Jamieson, 1995). Moreover, frequency of ambient noise concentrates at low frequency region. Taking this into consideration Wise (2003) investigated effect of prescriptive formula on tinnitus suppression. It was reported that 80 % of individuals with tinnitus experienced less audible tinnitus when hearing aids were programmed according to the DSL (i/o) v4.0 than to NAL-NL1 prescription. Hence it was recommended to fit the hearing aid with DSL (i/o) prescriptive formula. From literature it is clear that by varying setting in hearing aid suppress the tinnitus.

However, individuals who are fitted with hearing aid having tinnitus suffer more in quiet environment than during conversation. Thus, in present study, hearing aid is programmed in various strategies to investigate relief from tinnitus, especially in quiet condition. In each strategy of hearing aid on acoustic output at the ear canal is objectively recorded using probe tube microphone measurement.

In addition, behavioral paired comparison method is utilized to find out best hearing aid strategy suits to provide relief from tinnitus, in quiet condition. It is hypothesized that none of the combination of strategies in hearing aid receive relief from tinnitus.

1.1. Need for the study

The experimental studies have proved that in majority of subjects on whom tinnitus audibility was reduced after fitted with hearing aid. This is because hearing aid amplifies speech during conversation effectively masks tinnitus and consequently a qualitative and a quantitative data were collected from them reports benefit from hearing aid on tinnitus relief. However, its effect in quiet condition is questionable. Most of the hearing aid users who self-reported tinnitus is still be perceived in quiet condition. Thus, there is a need to know the best strategy in hearing aid that can increase the ambient noise and provide relief from tinnitus.

1.2. Aim of the study

To investigate the best amplification strategy that provides tinnitus relief in a quiet environment.

1.3.Objectives

The following objectives were utilized in each group to investigate the aim of the study

1. To document the minimum masking level on tinnitus suppression.
2. To find the relation between MML at tinnitus pitch and gain at tinnitus pitch in each strategy of hearing aid.
3. To compare amplification strategies on tinnitus relief using paired comparison method.

Chapter 2

Review of literature

The focus of the study was to investigate the best strategy in hearing aid provides tinnitus relief in quiet environment. In relation to the same, relevant studies on the topic are reviewed and it is discussed under the following headings:

1. Incidence and Prevalence of Tinnitus
2. Hearing loss relation to tinnitus pitch
3. Tinnitus Assessment: Minimum Masking Levels
4. Tinnitus Outcome Measures
5. Hearing Aids and Tinnitus Relief
6. Optimization of Hearing Aids for Tinnitus Relief

2.1. Prevalance and Incidence of Tinnitus

Tinnitus is most common complaint in those individuals having hearing loss. A retrospective study was conducted by Thirunavukkarasu and Geetha (2013) for one year of period prevalence. Their report suggests a prevalence of tinnitus in geriatrics individuals with otological problems were 16.8% in >60 years of age. Gender wise analysis in them reported of 60.9% of males and 39.1% of females were affected from tinnitus. The study also reported that tinnitus was seen more in sensorineural type of hearing loss (64%), followed by mixed hearing loss (33.4%) and conductive hearing loss (14%). Among degree of hearing loss, moderate degree of hearing loss had more prevalence of tinnitus percept

compared other degree of hearing loss. Western studies have also reports similar findings. Schwaber (2003) agrees that the majority of people report tinnitus between the age ranged from 40 to 70 years. While tinnitus occurs in individuals of all ages, it occurs most commonly in older adults. In yet another study, Davis (1995) finds that the incidence of tinnitus was approximately 10.2% in the adult population and rises after the age of 50 years. Approximately 50% of people with hearing loss experience tinnitus (Davis, 1998). Further, a more significant difference is reported between men and women with 12% of men over age 65years reporting tinnitus, compared with 7% of women (National Centre for Health Statistics, 1960-1962). Subjective tinnitus is found to be present in about 85% of the individuals seeking help from an otologist (McFadden, 1982). It affects around 15% of the world population and this prevalence increases to 33% in individuals aged over 60 years (Jastreboff, 1990). Tinnitus may be associated with more than 300 diseases.

To summaries, tinnitus prevalence was peaked with advance in age. It is commonly seen individual with hearing loss, especially moderate degree of hearing loss.

2.2. Hearing loss relation to tinnitus pitch

Schaette and Kempter (2009) conducted an experimental design in which they have reported that tinnitus pitch is related to hyperactivity of auditory nerve

and said that tinnitus pitch can be predicted from audiograms. They found that that decreased auditory activity due to hearing loss is counteracted by an increase in neural response gain. The increased neural response gain in effect restores the mean firing rate, but also leads to hyperactivity in the central auditory neurons. They revealed that patterns of hyperactivity are strongest at frequencies close to perceived tinnitus pitch which correlates with patient's audiogram having maximum hearing loss. In the similar line of study Schecklman et.al (2012) examined the relationship between the tinnitus pitch and audiometric slope in 286 patients. The audiogram edge was defined as the lower frequency of two neighboring frequency pairs in the audiogram with the largest steepness. Tinnitus pitch was assessed upto frequency limit of clinical audiometry. Bracketing method was employed in which frequency of tone was changed by 1 Hz to find the pitch of the tinnitus in each ear. If the nature of tinnitus is noise then similar procedure was performed but instead of tone, narrow band noise was used to determine the tinnitus pitch. In case of a narrow band noise an octave or 1/3-octave filter bank with standard mid frequency was used. Irrespective of nature of tinnitus, the tone/noise was changed accurately by 1 Hz step size such that a center frequency of the matching signal was measure which closely represents the pitch of the tinnitus. In addition, the frequency of the maximum hearing loss was evaluated for each subject. A correlation coefficients performed to find correlation between the tinnitus pitch and edge frequency; and tinnitus pitch and frequency of maximum hearing loss. There was a significant relation between the

tinnitus pitch and maximum hearing loss than the frequency edge (less significant).

To conclude pitch of the tinnitus was determined from maximum hearing loss observed in audiogram.

2.3. Tinnitus assessment using Masking procedure

In the assessment of tinnitus, information about the pitch and loudness of tinnitus can be obtained by Minimum Masking Levels (MML). This method was proposed by Feldmann(1971).The individuals with tinnitus are presented with narrow band noises of different frequencies to the ear in which tinnitus is present in an ascending runs. They are instructed to indicate the intensity of narrow band noise which is just sufficient to mask the tinnitus. This value is the Minimum Masking Level (MML).A value of MML is plotted as a function of frequencies. The physiology behind this process is lateral inhibition at the neural level. The stimulation from the external source (noise) spreads and reduces the pathological spontaneous activity. The findings of Penner (1987) infer that the level of noise required to mask the tinnitus at the pitch was generally lowest than at other frequencies. In high pitch tinnitus, the masker level required to mask tinnitus seems to be higher at the high frequencies than low frequencies (Zwicker, 1974). To sum up, the MML is best method to determine the tinnitus pitch and loudness.

2.4. Tinnitus outcome measure

In categorizing groups and assessing treatment outcome if any is qualitatively measured using quaternaries. Searchfield and Kaur (2010) studied the handicap from tinnitus by providing counseling alone and hearing aid fitted with counseling. To assess handicap of tinnitus they have used Tinnitus Handicap Questionnaire (THI). The results showed a significant reduction in scores in THI for those individuals who are provided with both amplification and counseling than counseling alone. It was observed that THI found to be best outcome measure to document the effect of treatment on tinnitus.

Baguley, Humphriss and Hodgson (2000) reported that Tinnitus Handicap Inventory is best suited for quantification of self-perceived handicap. THI has high congruent validity. Baguley and Anderson (2003) also reported that THI has high test retest reliability, high internal consistency, and high congruent validity. Hence, Tinnitus Handicap Inventory can be used in the field of research and clinical because of its high test retest reliability. THI is a qualitative outcome measure that plays an important role in assessing tinnitus on the daily routine, emotions, distress due to tinnitus and communication skills.

2.5. Tinnitus relief through Hearing aid

One of the treatment approaches for tinnitus is acoustic stimulation through hearing aid. Newman, Sandridge, Meit and Cherian (2008) states that

hearing aid amplification is useful for managing tinnitus in two ways. Firstly, hearing aids amplify ambient background noise which may simply cover up or mask the patient's perception of tinnitus. Second, while wearing hearing aids, the patient improves their communication ability, likely leading to a reduction of stress. Kochkin and Tyler (2008) reported the effectiveness of tinnitus treatment using hearing aid by carrying out a online survey in 230 hearing care professionals. Results showed that 60% of individuals experienced relief from tinnitus via hearing aid and 88% of the health care professionals recommended the clients to use hearing aids as it improves quality of life by improving hearing, motivation of individuals. Alessandra, Giorgia and Alberto (2012) conducted a case study on a 67 year old woman with unilateral sudden hearing loss in right ear suffering from severe tinnitus in the same ear since 18 months. There was reduction in tinnitus with use of hearing aid which was concluded based on evaluation for every 3 months. Hoare, Edmondson, Sereda, Akeroyrd, and Hall (2014) found the effectiveness of hearing aid amplification for patients with tinnitus and co-existing hearing loss. Study has recruited adults with age 18 years and above with hearing loss. Intervention included hearing aid fitting. Outcome measures included rating scale: '0' indicating 'No tinnitus' and '10' indicating 'As loudness as you can imagine'. There was reduction in tinnitus from severe to moderate scores. De Melo Araujo and Iório (2015) also found the effect of sound amplification in self-perception of tinnitus and hearing loss in 24 elderly subjects with the age ranged from 60-70 years. All of them had moderate degree of sensorineural hearing loss. Binaural multichannel hearing aid was fitted. Results

revealed that there was a relief from tinnitus after 3 months of continuous usage of hearing aid. It was also observed and reported that the tinnitus relief was seen only after continuous usage of hearing aid for at least 8 hours per day. McNeil et. al (2012) conducted a retrospective study by reviewing 70 cases with the mean age of 55 years. Tinnitus assessment was conducted in soundproof room with the headphones. Participants were presented with two 10 dB SL pure tones at a time on the ear opposite to the loudest tinnitus and were asked to compare the two tones (e.g. 0.5 and 4 kHz) and identify the tone closer to the tinnitus pitch .The frequency of presented tones was then narrowed down till the tinnitus pitch was matched. The procedure was repeated three times for consistency of results. Tinnitus reaction questionnaire was administered to measure the tinnitus distress prior to the fitting of hearing aid and 3 months post fitting. Partial masking was seen in 47% and 23% of them reported no masking. Whereas individuals with high tinnitus pitch did not report of masking in their study. The study concluded that fitting of hearing aid can reduce intensity of tinnitus and also suppress to a larger extent. A larger reduction in tinnitus was seen in those whose tinnitus pitch fell in the frequency range of the hearing aids, with a good frequency range and those who had low TRQ scores. To conclude, hearing aid is found to be the best treatment strategy utilized to tackle both reduced audibility and ringing sensation in ear. With advance in hearing aid technology, the option available in it is manipulated that best suits in reducing the audibility of tinnitus provides maximum relief from tinnitus.

2.6. Optimizing hearing aid setting on tinnitus suppression

2.6.1. Open fit hearing aid

Ferrari, Sanchez and Pedalini, (2007) compared the efficacy of vented ear moulds with pressure vented ear moulds. Pressure vented ear moulds was preferred by individuals with flat hearing loss, while vented ear moulds were preferred by those with sloping hearing loss. Overall the presence of vent in the ear mould led to the relief from tinnitus as the low frequency information transferred at 500 Hz and 1000Hz through the mould. Parazzinni, Del Bo, Jasterboff and Tagnola (2014) found the efficacy of open fit hearing aids in tinnitus therapy in comparison to sound generators. Participants were 91 in number who were divided into two groups. One group was treated with open fit hearing aids and another group with sound generator. Outcome measures such as Visual Analog Scale (VAS) and Tinnitus Handicap Inventory (THI) were administered at 3, 6 and 12 months. The effectiveness of sound generators and hearing aid with Tinnitus Retraining Therapy TRT was compared. Result revealed in every 3 months it was observed significant improvement in both open fit ear hearing aids and sound generators. Even in TRT it was observed that open hearing aid and noise generator assigned to each group showed reduced tinnitus on visual analog scale and reduced handicap.

2.6.2. Unilateral versus bilateral

Brooks and Bulmer (1981) conducted a survey on 249 adults having hearing loss. Questionnaires were mailed to each of them after 3 months hearing aids usage. Individuals were grouped based on how long they adapt to their hearing aid. A group of 155 who have responded to mail in whom 71 subjects had tinnitus. Nine individuals reported a reduction in tinnitus with monoural hearing aid and 47 of them reported suppression in tinnitus with bilateral hearing aids and rest of the participant find no reduction of tinnitus from hearing aid.

2.6.3. Naïve hearing aid user

Surr, Montgomery and Mueller (1985) investigated the effect of amplification on tinnitus in 200 naïve hearing aid users. Hearing aid was programmed based on the hearing loss without giving additional modification in hearing aid. It was reported that half of the participants experienced reduction in severity of tinnitus. Amount of tinnitus relief varied from partial to severe reduction. The probable reason could be a tinnitus gets masked by the amplified environmental sounds and internal noise present within the hearing aid provided a relief from tinnitus to their participants (Vernon, Johnson, & Schleuning, 1980). Melin, Scott, Lindberg, Lyttkens (1987) conducted a study in thirty nine subjects who had hearing loss with tinnitus were with fitted with hearing aid with no experience. Subjects reported of partial relief from tinnitus which was measured based on Visual Analog Scale. Tinnitus reduction was seen for those who use hearing aid for longer hours than who uses shorter hours a day. Zagólski,(2006)

found tinnitus relief in patients with presbycusis. Patients were 33 in number with age range of 60 years and above. All subjects were naïve hearing aid users. Immediate relief in tinnitus loudness was found in 28 patients after fitting hearing aid. Among 28, complete relief was seen in 18 subjects with first fitting.

2.6.4. Compression knee point

Wise (2003) studied the impact of compression kneepoint on tinnitus suppression along with comparison of NAL –NL1 and DSL (i/o) v-5. For reducing the audibility of tinnitus, she recommended use of multiprogrammable hearing aid with a separate program. It was observed that 80% reduction in tinnitus awareness was documented with low compression knee point, irrespective of prescriptive formula. This was attributed to more amplification was provided to a low intensity of low frequency ambient noise and this in turn masks the tinnitus.

2.6.5. Digital Noise Reduction

The presence of tinnitus exacerbates in silence. The relief of tinnitus occurs when the individuals are exposed to some amount of background environmental sounds. This happens when the directional sensitivity of the microphone of the hearing aid is omnidirectional. Individual with tinnitus can take maximum advantage of diffuse ambient noise for the masking of their tinnitus through omnidirectional microphones (Ricketts & Mueller, 2015). In addition switch off of digital noise reduction algorithm does not reduce the gain at bands wherever lesser SNRs are present. This allows the ambient noise to be audible to the individuals with tinnitus. Hence digital noise reduction is recommended to be

switched off for and omnidirection sensitivity of microphone should be activated for tinnitus relief (Ricketts & Mueller, 2015)

2.6.6. Prescriptive formula (DSL versus NAL NL1)

Shekhawat, Searchfield, Kobayashi and Stinear (2013) demonstrated relief of tinnitus from hearing aid in twenty five participants (mean age of 59 years, age range 34 – 81 years) in which 9 females and 16 males were recruited for the study. All had mild to moderate high-frequency sloping sensorineural hearing loss. Tinnitus pitch matching was done using 2 alternative forced choice method. The output of at varied gain (winner setting) were presented and investigated which one of them interferes more with their tinnitus. Result showed that winner setting decrease in tinnitus at 2k Hz more than 4 kHz when it was reduced by 6 dB. Winner gain was with 3 dB reduction than DSL (I/O) at < 4kHz and 2dB reduction at 4kHz-8kHz than DSL (I/O) v-5. It was concluded that higher the tinnitus pitch winner gain required was more to match the output of DSL(i/o)v5. For low frequency tinnitus winner gain was lower than DSL (i/o) v5 across all frequencies. Individuals with tinnitus can start their treatment with DSL i/o. However authors recommend a reduction of 3 dB across all frequencies for those individuals whose tinnitus pitch is < 4kHz.

To conclude options in hearing aid need to manipulate to obtain maximum relief on tinnitus. Almost all the experiment with hearing aid on tinnitus relief were conducted during conversation, or speech stimulus being presented in control condition to document the changes in tinnitus perception. Most of tinnitus

patients who wore hearing aid still complain of ringing sensation in quiet condition. Thus, in present study, strategy in hearing aid was manipulated to obtain the maximum relief from tinnitus, in quiet environment.

Chapter 3

Method

A one shot posttest only and randomized repeated measures research design was utilized to study the best program that gives relief from tinnitus in quiet environment**.**

3.1. Participants selection criteria

A total of 14 participants were involved in the study with the age ranged from 20 years to 80 years. They were classified into three groups: mild (N=4) , moderate (N=4) and severe (N=6). These groups were formed based on severity of communication handicap from tinnitus using Tinnitus Handicap Index (THI). Those individuals whose hearing sensitivity range from 26 dB HL to 40 dB HL in 250 Hz to 2 kHz (in octave) and 65 dB HL to 80dB HL in >2 kHz to 8 kHz (in octave) were recruited in the study. All the study participants had sloping sensorineural hearing loss with unilateral or bilateral tinnitus in them. Each participant had normal middle ear status as indicated by type 'A' tympanogram. The selected participants should be native speaker of Kannada and none of the participants had experience with hearing aid and any other complain of neurological, psychological and cognitive problems.

Table-3.1: The details of the participants are as follows

Groups	Age(yrs)	Tinnitus pitch	Minimum masking level (SPL)	THI raw scores
Mild	58	6000	92	28
Mild	60	3000	70	28
Mild	56	2000	65	25
Mild	45	750	71	28
Moderate	33	4000	68	55
Moderate	58	2000	80	40
Moderate	52	1000	64	47
Moderate	53	250	64	40
Severe	58	250	74	52
Severe	72	3000	79	65
Severe	33	3000	91	68
Severe	35	3000	74	64
Severe	45	1500	63	68
Severe	48	500	86	76

3.2. Test environment

Testing procedure was carried out in a sound treated double room, with the ambient noise levels within permissible limits as recommended by ANSI (1999).

3.3. Instrumentation

1. A calibrated diagnostic two channel audiometer Inventis Piano with head phone were used to obtain hearing sensitivity in air conduction mode, tinnitus pitch evaluation, minimum masking level and speech identification score from each participant. In addition bone vibrator was used to obtain bone conduction threshold.

2. Immittance audiometer (GSI 61 Version 2) was used for evaluation of middle ear status.

3. Receiver in the canal (RIC) SORINO X-MINI P digital hearing aid was used which had options to switch off noise reduction circuit, change the directionality and vary compression thresholds.

4. A hardware HIPRO connected to a personal laptop was loaded with NOAH (v-3) software, particular hearing aid software and WinChap (v-3) (a software control the operation of FONIX 7000 hearing aid analyzer) which were used to program and verify the gain in the RIC hearing aid.

5. Fonix 7000 hearing aid analyzer was used to verify the gain set in hearing aid and also to measure the output and gain of the hearing aid at the participant test ear of ear canal at different program settings.

3.4. Procedure

The following procedures were utilized for subject selection and to study the manipulation of gain in hearing aid on relief of tinnitus in quiet environment.

1. The pure tone thresholds for air conduction at octave frequencies from 250 Hz to 8 kHz were obtained using +10 and -5 dB procedure as specified by Carhart & Jerger (1959). The bone conduction thresholds from 250 Hz to 4 kHz were identified using similar procedure.

2. One of the lists of phonetically balanced word list developed by Yathiraj and Vijayalakshmi (2005) was presented through headphones. The participants were instructed to repeat the words heard. The number of correctly identified words were counted and converted into percentage.

3. Tympanometry was carried out using 226Hz probe frequency and pressure rate was varied from 200/600 daPa. Ipsilateral and contralateral reflexes were found at 500 to 4 k Hz (in octave) by varying the intensity insteps of 5 dB to notice a minimum change in the compliance of tympanic membrane.

3.4.1. Tinnitus Handicap Inventory

Tinnitus Handicap Inventory developed by Newman, Jacobson and Spitzer (1996) is a qualitative questionnaire in English language which comprised of 25 items. A standardized Kannada version of the test developed by Zacharia, Naik, Sada, Kuniyil and Dwarakanath, (2012) was administered to each participant of study group and each question was rated on a three point rating scale 'yes' as 4, 'sometimes' as 2, and 'no' as zero. The maximum score that can be obtained from this te st battery is 100. The scoring pattern are 2-16 slight, 18-36 mild, 38-56 moderate, 58-76 severe and 78-100 catastrophic.

3.4.2. Tinnitus Pitch

To obtain the tinnitus pitch, A standardized procedure by Henry, Jastreboff, Jastreboff, Schechter and Fausti (2002) was adopted. Tinnitus pitch quantifies the frequency of Tinnitus. The procedure includes presentation of a tone to each participants in octave frequency ranged from 250 Hz to 8000 Hz. Participants were asked to report whether the tone was too high , low or very low compared to their tinnitus pitch. Each tone was presented at 15 dB SL and was instructed to choose the tone which closely matched to their tinnitus. The pitch at which participant indicated it as same, or the nearest as that of their tinnitus was considered as the tinnitus pitch.

3.4.3. Minimum Masking Level on Suppression of Tinnitus

The minimum level at each frequency masks tinnitus is defined as minimum masking level (MML). A narrow band noise was presented at threshold level at each test frequency (250Hz, 500 Hz, 750Hz, 1000Hz, 1500 Hz, 2000Hz, 3000Hz, 4000Hz, 6000Hz and 8000Hz) and its level was increased in 1 dB step size till it masks the tinnitus. Participant was instructed to report the minimum level of noise completely masks the tinnitus. The procedure was repeated three times for the consistency of result. In participants with unilateral tinnitus, narrow band noise was presented in the ear having tinnitus. However, in bilateral tinnitus participants, the ear having louder tinnitus was selected to present external noise. A relative gain as a function of frequency was calculated by taking the difference between MML at each frequency and MML at tinnitus pitch.

3.4.4. Hearing aid output at ear canal from different processing strategy

The participant was seated at 12 inch distance from loudspeaker. The position of loudspeaker was placed at 45^0azimuth in reference to the test ear having tinnitus. The probe microphone of the Fonix 7000 system was inserted into the ear canal of the participant. The probe tip detached from probe unit to mark 5 mm past the end of the doom of RIC hearing aid. Later the probe tip was attached to probe unit and was inserted into the ear canal till the marking of probe tube was visible at tragal notch. After the insertion of probe tube into the ear canal, levelling was performed. A personal laptop loaded with WinChap (v-3) was connected to

the FONIX 7000 hearing aid analyser. This software controls the operation of hearing aid analyzer. A digi speech at 65 dB SPL was presented and the output was measured at different frequencies (250 Hz to 8 k Hz in octave) and the resulting curve termed it as real ear unaided response (REUR).

A hardware HIPRO connected to the same personal laptop loaded with hearing aid software to program the Sorino X Mini RIC hearing aid. Prescriptive formula NAL- NL1 at low compression threshold (30 dB SLP) was activated. Further, noise reduction circuit was switched off and directional microphone was disabled. Once the hearing aid was programmed with respect to participants hearing loss, it was fitted without changing the position of probe tip at the ear canal. Real ear aided responses at different frequencies (250 Hz to 8 kHz in ocatve) were measured for digi speech presented at 65 dB SPL. Finally, instrument automatically calculates real ear insertion response by taking the difference between REAR and REUR at each frequency (250 Hz to 8 kHz in ocatve). It was ensured that gain of hearing aid at each frequency was almost matched with the prescriptive target. In addition, the gain of the hearing aid was optimized by presenting recorded Ling's six sounds, which were presented sequentially at 65 dB SPL through loudspeaker. Depending upon the response for each Ling sound the gain with respect to the spectrum of each sound was programmed. Further, gain at tinnitus pitch was increased till the ringing sensation was completely masked (P1). Similar procedure was carried out by changing only the compression threshold from 30 dB SPL to 50 dB SPL (P2). The entire procedure was performed by programming the hearing aid

using DSL i/o (v-5) prescriptive formula at compression thresholds 30 dB SLP (P3) and 50 dB SPL (P4), respectively.

3.4.5. Rating the amplification processing strategy on suppression of tinnitus using paired comparison method

A paired comparison judgment was used to obtain the best program of hearing aid which gives tinnitus relief. A total of six comparisons (P1, P2, P3 and P4) were made. Each participant was instructed to choose one program which gave best relief from tinnitus against other program by listening to the ambient noise presented at 30 dB SPL delivered through loudspeaker. A best program was selected from a total of six comparisons using Round Robin Tournament format. A preference score of one mark was assigned for the best program. Likewise three trials were performed and it was ensured these six comparisons in each trial were randomized. Finally the number of times each program give relief was noted down.

3.5. Statistical analyses

1. Descriptive statistics was carried out to determine the mean and standard deviation of different program preferred by the participants.
2. A non parametric Friedman test was performed to compare the preference program among the four programs.
3. Spearman's correlation was carried out to find the relationship between Minimal Masking Level at tinnitus pitch and gain at the tinnitus pitch in each program.

Chapter 4

Results

The aim of the study was to investigate the best amplification strategy that gives relief from tinnitus in a quiet environment. Participants were grouped as mild, moderate and severe groups based on Tinnitus Handicap Index (THI) values. From each group, Minimal Masking Level (MML) was analyzed descriptively. A four programs are P1 (DSL i/0 v -5 at compression threshold of 30 dB SPL), P2 (DSL i/0 v -5 at compression threshold of 50 dB SPL), P3 (NAL-NL1 at Compression Threshold of 30 dB SPL) and P4(NAL-NL1 at Compression threshold of 50 dB SPL) were utilized to select the best program that provides tinnitus relief in a quiet environment using paired comparison method. Further, relation between gain at tinnitus pitch in each program and MML at tinnitus pitch was determined. These data were subjected to statistical analyses using SPSS [Statistical Package for Social Sciences] software of version 17.

4.1. Minimum Masking Level

Figures 1, 2 and 3 represents a relative gain plotted as a function of frequency from participants of each group. Black dot represents the pitch of the tinnitus. Over all it is observed that, irrespective of group, at low pitch tinnitus (250 Hz, 500 Hz and 750 Hz) a higher amount of masking level was required to suppress the tinnitus. In addition, participants who had tinnitus at frequencies;
1 kHz, 2 kHz and 4 kHz required more level of masking noise required at below and above tinnitus pitch than at tinnitus pitch. Further, it is also found that

immediate adjacent frequencies (above and below) near tinnitus pitch required less noise level to suppress tinnitus. However, far frequencies with respect to tinnitus pitch required more level of noise to suppress tinnitus. Similar observation was found in moderate and severe groups.

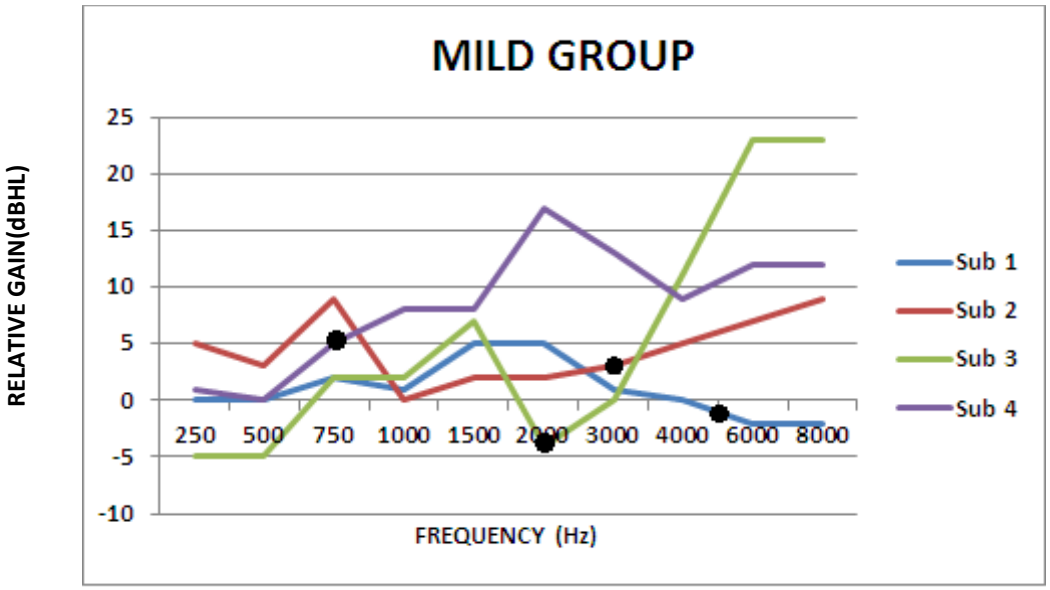

Figure 4.1: Relative gain as a function of frequency for mild group

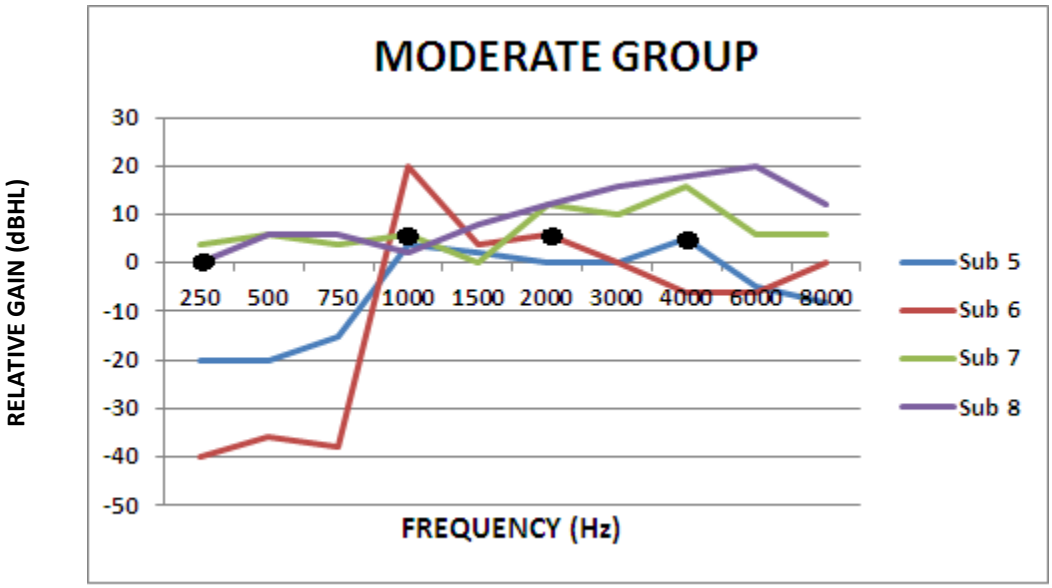

Figure 4. 2: Relative gain as a function of frequency for moderate group

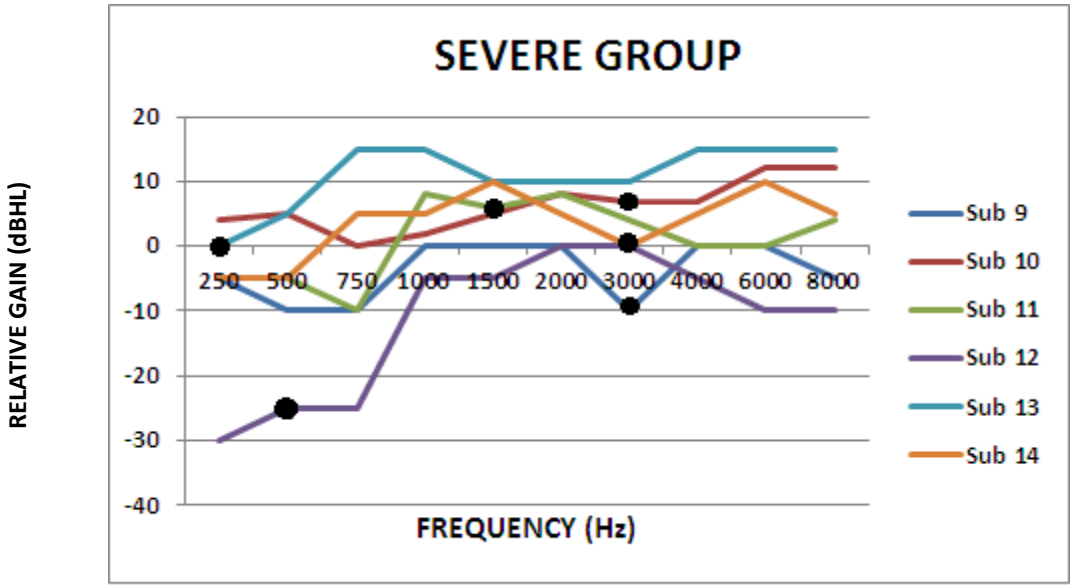

Figure 4.3: Relative gain as a function of frequency for severe group

4.2. Relation between MML at tinnitus pitch and gain at tinnitus pitch

Spearman's correlation was performed to measure the correlation between MML at tinnitus pitch and amount of gain provided at each program. A negative correlation was found between MML at tinnitus pitch and gain provided by hearing aid at each program which was found no significantly different in P1 (N=14,*rs*= -1.94, p >.05) in P2 (N=14 r_s= -.144 , p >.05)in P3 (N=14 r_s= -142, p >.05) in P4 (N=14 r_s= -.144, p >.05).

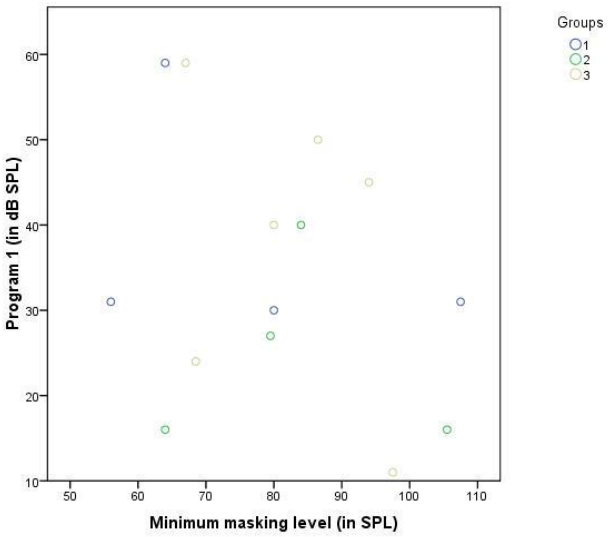

Figure 4.4. Correlation between MML at tinnitus pitch and gain in P1 at tinnitus pitch (1= mild; 2= moderate; and 3=severe group)

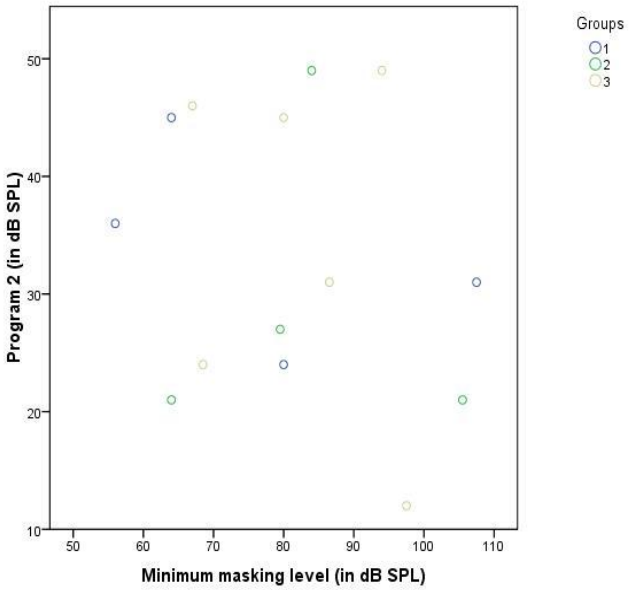

Figure 4.5. Correlation between MML at tinnitus pitch and gain in P2 at tinnitus pitch(1= mild; 2= moderate; and 3=severe group)

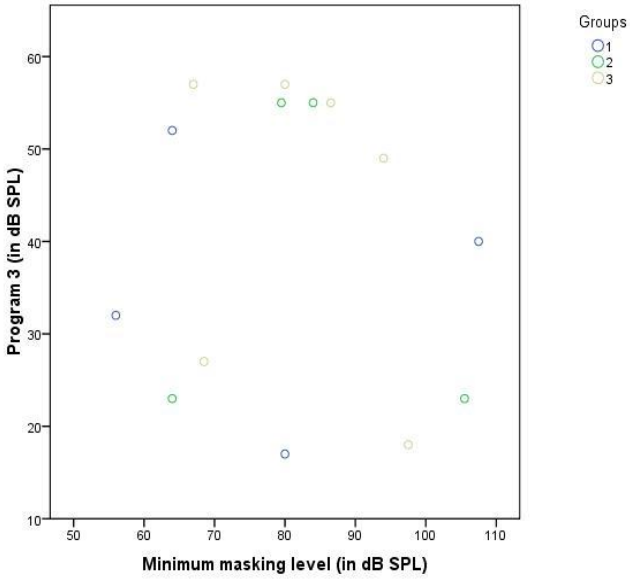

Figure 4.6. Correlation between MML at tinnitus pitch and gain in P3 at tinnitus pitch (1= mild; 2= moderate; and 3=severe group)

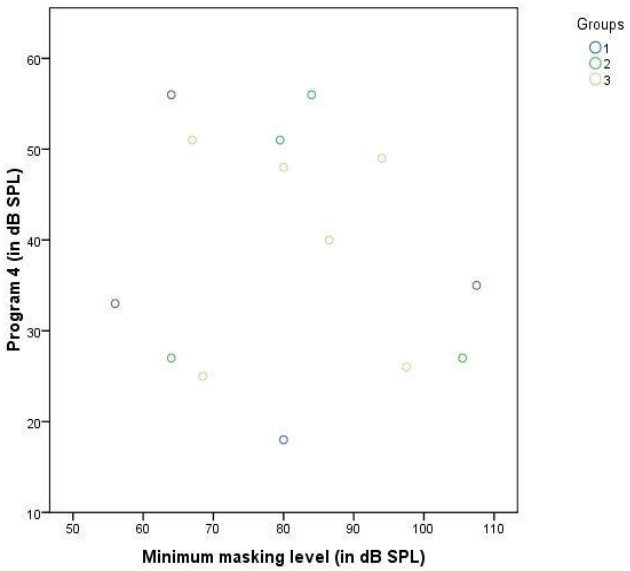

Figure 4.7. Correlation between MML at tinnitus pitch and gain in P4 at tinnitus pitch(1= mild; 2= moderate; and 3=severe group)

4.3 Paired Comparison

Friedman test was performed to compare preference program among four on tinnitus relief from the study participants in each group. Differences in mean preference among the four programs for participants of mild group showed that there was no significance difference [χ^2 (3) = 5.750, p > .01]. Similar findings were observed in mild [χ^2 (3) = 3.250 p > .01] and I severe group [χ^2 (3) = 3.333 ,p > .01] groups indicating no significant difference in the mean preference among the four programs.

4.4 Preference percentage

The preference of best program on suppression of tinnitus was found by Round Robin tournament. In mild group, out of 4 participants, 25% (1 participant)of them preferred P4 (NAL-NL1 prescriptive formula with a compression threshold of 50dBSPL) and 75% (3 participants) of them preferred P2 (DSL i/o (v-5) compression threshold 50 dBSPL) on tinnitus relief. In moderate group, out of 4 participants, 75% (4 participants) of them preferred P4 (NAL NL1 compression threshold 50 dB SPL)and 25% (1 participant) of them preferred P3 (NAL NL1 compression threshold 30 dB SPL) on tinnitus relief. In severe group, out of 6 participants, 66.7% (4 participants) of them preferred P4 (NAL NL1 compression threshold 50 dB SPL) and 16.7% (2 participants) showed preference to each of P2 (DSL i/o (v-5), compression threshold 50 dB SPL) and P3 (NAL NL1, compression threshold 30 dB SPL) on tinnitus relief, respectively.

Chapter 5

Discussion

The aim of the present study was to find the best amplification strategy on tinnitus relief in quiet environment for individuals with sensorineural hearing loss. It was found in each group, three patterns were observed from MML. At high pitch tinnitus, basal part of cochlea exits even in absence of stimulation (phantom perception). For it to suppress, low frequency noise level required was way high. This is because all the participants had minimal to mild hearing loss at low frequency region and it generally stimulates at apical region of cochlea required more level of noise to just mask the tinnitus at high pitch, which exits at basal part of cochlea. In addition, high frequency stimulation above high-pitched tinnitus required high level of noise for it to mask. This could be attributed to more number of outer hair cells damage and consequent loosening of basilar membrane stiffness at basal part of cochlea, which reflected in high frequency hearing loss. Further, high frequency stimulation above high pitch tinnitus excites at basal turn and required high level of noise to suppress tinnitus. At low pitch tinnitus, apical part of cochlea exits in the absence of stimulation. It was found that higher level of masking noise at high frequency was required for it to suppress than at tinnitus pitch. The reason could be loss at high frequencies and presentation of high frequency noise level excites basal turn of cochlea would requires more level of noise to suppress low pitch tinnitus exits at apical region of cochlea. However, tinnitus suppression at mid pitch required higher amount of

noise at high frequency than at low frequency. This is because poorer threshold at high frequency exits at basal turn of cochlea required more level for it to suppress the tinnitus, which excites at middle portion of cochlea turn.

In addition, it was found that there was no correlation between MML at the tinnitus pitch and the gain at the tinnitus pitch. This clearly indicates that the loudness of tinnitus and the amount of gain required to obtain tinnitus relief are not directly linked. This is because tinnitus loudness is independent irrespective of hearing loss (Goodwin & Johnson, 1980). However, gain in hearing aid is dependent on degree of hearing loss. These discrepancies perhaps have caused no relation between tinnitus loudness and gain set in hearing aid at tinnitus pitch on tinnitus relief.

In each group, mean preference scores among the four programs showed no significant difference. This could be because in each program the gain was set at tinnitus pitch. That is irrespective of prescriptive formulas in which compression threshold kept at either low (30 dB SPL) or high (50 dB SPL), the ambient noise presented at 30 dB SPL was amplified and provided equal preference on tinnitus relief. The result of mean preference score of the present study is contradictory to the previous research conducted by wise (2003) who reported DSL i/o with low compression threshold provided maximum relief from tinnitus, in quiet environment. This discrepancy between the present study and the research findings of Wise (2003) could be due to methodological concern. In the

present study, each program was set in the receiver in the canal digital hearing aid with extended high frequency amplification. In addition, omni directionality was switch off and DNR was deactivated. Further, each program was optimized such that gain was set at tinnitus pitch. These modifications were common in each program set in hearing aid amplified the ambient noise presented at 30 dB SPL have effectively shown relief from tinnitus. Thus, the effects of prescriptive formula and compression threshold have negligible impact on tinnitus relief.

In preference percentage score of choosing the best amplification, a total of each 75 % of participants in mild (3/4) and in moderate (3/4) group preferred DSL i/o v5 (with CT of 50 dB SPL) and NAL NL1 (with CT of 30 dB SPL) prescriptive formula, respectively, on tinnitus relief. However, in severe group, a total of 66 .6 % (4/6) of participants preferred NAL Nl-1 (with CT of 50 dB SPL) prescriptive formula on tinnitus relief. The exact attributed reason on preference percentage score on tinnitus relief was not known.

A caution must be taken in fitting hearing aid to amplify ambient noise for tinnitus relief. A greater proportion of hearing aid users might achieve tinnitus masking if greater emphasis is placed on amplification of ambient sounds (Searchfield & Tyler, 2006) but this also must be balanced against potential reduction in hearing satisfaction. To conclude, if the subject complains of tinnitus in quiet condition after wearing hearing aid, then option available in it (open fit, directionality off, omnidirection on, wide bandwidth, gain set at tinnitus pitch,

either NAL NL-1 or DSL i/o v5 formula, low or high kneepoint) shall be carefully handled to amplify the ambient noise. This can be set as separate program such that it can give a maximum relief from tinnitus especially in quiet condition.

Chapter 6

Summary and Conclusion

Even after fitted with hearing aid, tinnitus perception is a bothersome to many individuals especially in quiet environment. Hence this study was taken up to find the best amplification strategy that suppresses the tinnitus in quiet environment. A total of fourteen participants were recruited. Further, these participants were grouped into three based on test scores of THI. A test RIC digital open fit hearing aid was used in which four programs were activated by two prescriptive formulas with low and high compression thresholds. From each participant, minimum masking level was measured. In addition the best program from four that suits tinnitus relief was identified by presenting ambient noise at 30 dBSPL delivered through loudspeaker.

MML at tinnitus pitch showed the amount of noise required at the region of Tinnitus Pitch was lesser than other frequencies. In addition it was observed that there was no correlation between MML at tinnitus pitch and gain at tinnitus pitch. Further none of the programs showed significant preference on tinnitus relief. Participants preference percentage showed a total of each 75 % of participants in mild (3/4) and in moderate (3/4) group preferred DSL i/o v5 (with CT of 50 dB SPL) and NAL NL1 (with CT of 30 dB SPL) prescriptive formula, respectively, on tinnitus relief. However, a total of 66 .6 % (4/6) of participants preferred NAL Nl-1 (with CT of 50 dB SPL) prescriptive formula on tinnitus relief. The exact attributed reason on preference percentage score was not known.

The findings infer if hearing aid options which increases ambient noise were selected then effect of prescriptive formula and compression threshold have negative effect on tinnitus relief in quiet environment.

Implication

Hearing aid gain prescribed to hearing loss by either NAL-NL1 DSL i/o prescriptive formula with compression threshold at low or high have negligible effect on tinnitus relief. Thus, option available in hearing aid which amplifies ambient noise are selected suitably in a separate program for tinnitus relief especially in quiet condition.

References

Baguley, D. M., & Andersson, G. (2003). Factor Analysis of the Tinnitus Handicap Inventory. *American Journal of Audiology*, *12*, 31–34.

Baguley, D., Humphriss, R., & Hodgson, C. (2000). Convergent validity of the tinnitus handicap inventory and the tinnitus questionnaire. *Journal of Laryngology & Otology*, *114*(11), 840-843.

Brooks, D. N., & Bulrner, D. (1981). Survey of binaural hearing aid users. *Ear and Hearing*, *2*(5), 220-224.

Cornelisse, L. E., Seewald, R. C., & Jamieson, D. G. (1995). The input/output formula: A theoretical approach to the fitting of personal amplification devices. *The Journal of the Acoustical Society of America, 97* (3), 1854-1864.

Davis, P. B. (1995). Living with Tinnitus Gore and Osment Publications.*Health Book Series, Sydney*.

Davis, A. C., Lovell, E. A., Smith, P. A., & Ferguson, M. A. (1998). The contribution of social noise to tinnitus in young people-a preliminary report.*Noise and Health*, *1*(1), 40.

de Melo Araujo, T., & Iório, M. C. M. (2015). Effects of sound amplification in self-perception of tinnitus and hearing loss in the elderly. *Brazilian Journal of Otorhinolaryngology*, 82(3),289-296.

Dillon, H. (1999). NAL-NL1: A new procedure for fitting non-linear hearing aids. *The Hearing Journal*, *52*(4), 10-12.

Feldmann, H. (1971). Homolateral and Contralateral Masking of Tinnitus by Noise-Bands and by Pure Tones. *International Journal of Audiology, 6091*, 138–144.

Ferrari, G. M. D. S., Sanchez, T. G., & Pedalini, M. E. B. (2007). The efficacy of open molds in controlling tinnitus. *Revista Brasileira de Otorrinolaringologia*, *73*(3), 370-377.

Goodwin, P. E., & Johnson, R. M. (1980). The loudness of tinnitus. *Acta oto-laryngologica*, *90*(1-6), 353-359.

Henry, J. A., Jastreboff, M. M., Jastreboff, P. J., Schechter, M. A., & Fausti, S. A. (2002). Assessment of patients for treatment with tinnitus retraining therapy. *Journal of the American Academy of Audiology*, *13*(10), 523-544.

Henry, J. A., Dennis, K. C., & Schechter, M. A. (2005). General Review of TinnitusPrevalence, Mechanisms, Effects, and Management. *Journal of Speech, Language, and Hearing Research*, *48*(5), 1204-1235.

Hoare, D. J., Edmondson-Jones, M., Sereda, M., Akeroyd, M. A., & Hall, D. (2014). Amplification with hearing aids for patients with tinnitus and co-existing hearing loss. *Cochrane Database Syst Rev*, *1*.

Jastreboff, P. J. (1990). Phantom auditory perception (tinnitus): mechanisms of generation and perception. *Neuroscience research*, *8*(4), 221-254

Kochkin, S., & Tyler, R. (2008), Tinnitus treatment and the effectiveness of hearing aids: Hearing care professional perceptions. *Hearing Review*, *15*(13), 14-18.

McFadden, D. (Ed.). (1982). *Tinnitus: Facts, theories, and treatments*. National Academies.

Melin, L., Scott, B., Lindberg, P., & Lyttkens, L. (1987). Hearing aids and tinnitus-an experimental group study. *British Journal of Audiology*, *21*(2), 91-97

Newman, C. W., Sandridge, S. A., Meit, S. S., & Cherian, N. (2008). Strategies for managing patients with tinnitus: A clinical pathway model.*Seminars in Hearing*, 29,(3),300-309).

Newman,C.W (1999).Audiologic management of tinnitus:Issues and options.*The Hearing Journal,52(11),*10-12

Norena, A. J., & Eggermont, J. J. (2003). Changes in spontaneous neural activity immediately after an acoustic trauma: implications for neural correlates of tinnitus. *Hearing Research*, *183*(1), 137-153

Parazzini, M., Del Bo, L., Jastreboff, M., Tognola, G., & Ravazzani, P. (2011). Open ear hearing aids in tinnitus therapy: An efficacy comparison with sound generators. *International Journal of Audiology*, *50*(8), 548-553.

Penner, M. J. (1987). Masking of tinnitus and central masking. *Journal of Speech, Language, and Hearing Research*, *30*(2), 147-152.

Ricketts, T., & Mueller, H. G. (1999). Making sense of directional microphone hearing aids. *American Journal of Audiology*, *8*(2), 117-127.

Schaette, R., & Kempter, R. (2009). Predicting tinnitus pitch from patients' audiograms with a computational model for the development of neuronal hyperactivity. *Journal of Neurophysiology*, *101*(6), 3042-3052.

Schecklmann, M., Vielsmeier, V., Steffens, T., Landgrebe, M., Langguth, B., & Kleinjung, T. (2012). Relationship between audiometric slope and tinnitus pitch in tinnitus patients: insights into the mechanisms of tinnitus generation.*PLoS One*, *7*(4), e34878.

Schwaber, M. K. (2003). Medical evaluation of tinnitus. *Otolaryngologic Clinics of North America*, *36*(2), 287-292.

Searchfield, G. D., & Tyler, R. S. (2006). Hearing aids and tinnitus. *Tinnitus treatment: Clinical protocols*, 161-175.

Searchfield, G. D., Kaur, M., & Martin, W. H. (2010). Hearing aids as an adjunct to counseling : Tinnitus patients who choose amplifi cation do better than those that don ' t. *International Journal of Audiology*, *49*, 574–579.

Shekhawat, G. S., Searchfield, G. D., Kobayashi, K., & Stinear, C. M. (2013). Prescription of hearing-aid output for tinnitus relief. *International Journal of Audiology*, 52, 617–625.

Surr, R. K., Montgomery, A. A., & Mueller, H. G. (1985). Effect of amplification on tinnitus among new hearing aid users. *Ear and hearing*, *6*(2), 71-75.

Surr, R. K., Kolb, J. A., Cord, M. T., & Garrus, N. P. (1999). Tinnitus Handicap Inventory (THI) as a hearing aid outcome measure. *Journal-American Academy of Audiology*, *10*, 489-495.

Thirunavukkarasu, K.& Geetha,C (2013). One-year prevalence and risk factors of tinnitus in older individuals with otological problems. *International Tinnitus Journal*, *18*(2), 175-181.

Vernon, J., Johnson, R., & Schleuning, A. (1980). The characteristics and natural history of tinnitus in Meniere's disease. *Otolaryngologic Clinics of North America*, *13*(4), 611-619.

Wegel, R., & Lane, C. E. (1924). The auditory masking of one pure tone by another and its probable relation to the dynamics of the inner ear. *Physical review*, *23*(2), 266

Wise, K. (2003). Amplification of sound for tinnitus management: A comparison of DSL [i/o] and NAL-NL1 prescriptive procedures and the influence of compression threshold on tinnitus audibility. *Section of Audiology, Auckland: University of Auckland*.

Zacharia, T., Naik, P. V., Sada, S., Kuniyil, J. G., & Dwarakanath, V. M. (2012). Development and standardization of tinnitus handicap inventory in Kannada. *Int Tinnitus J*, *17*(2), 117-23.

Zagólski, O. (2006). Management of tinnitus in patients with presbycusis.*International Tinnitus Journal*, *12*(2), 175.

Zwicker, E. (1974). On a psychoacoustical equivalent of tuning curves. In*Facts and models in hearing* (pp. 132-141). Springer Berlin Heidelberg.