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Communicative Profile Comparison between Children Using Hearing Aids and those Using Cochlear Implants

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Abstract

Background: The use of hearing aids (HA) or cochlear implantation (CI) can partially or fully restore hearing. Consequently speech production can improve over time and enters the normal rang when traditional amplification Devices (hearing aids) are unable to restore access to the full range of phonemic components of speech, a cochlear implant (CI) is a widely used treatment option for children with sensorineural hearing loss (SNHL).

Purpose: The aim of this study is to compare the functional benefit of the communicative skills of children with CI in relation to those using hearing aid in order to compare the role of each amplification device on the communicative abilities of severe to profound and profound sensorineural hearing impaired children.

Method: This study has a prospective design. It started after fitting all children with bilateral behind the ear hearing aids provided that the primary language assessment before rehabilitation is present in the medical files of these children. A 2nd language assessment was done after 12 months of language therapy to detect the progress of the language development to take the decision either to complete with hearing aids or to decide upon a cochlear implant. Then a 3rd language assessment was done after another 12 months of rehabilitation. These sixty patients were divided into two groups: Group A: Thirty children, who have used behind the ear hearing aids for two years and attended regular language therapy. Those children are not candidates for cochlear implants due to satisfactory progress with the hearing aids. Group B: Thirty children, who used bilateral behind the ear hearing aids and had regular language therapy for one year with poor response, so they shifted to cochlear implantation, and were enrolled in auditory training and language therapy for another year.

Results: Total language age of children using cochlear implant is significantly higher than that in the children while using hearing aids. Also, there is highly significant difference between frontal and back speech sounds in the children after implantation with positive correlation. Conclusion: cochlear implant is safe & reliable technique. The fact that many profoundly hearing impaired children using cochlear implant can develop functional levels of speech perception & production, develop competency level in a language other than their primary language and continuation of language therapy together with proper mapping accordingly is a must to enroll these children in main stream education.

Keywords: *Hearing Aids; Cochlear Implant; Language; Speech Intelligibility.*

Introduction

Language in children begins to develop since birth and is nearly complete by the age of 6 years. Language skills, speech quality, expressive and receptive vocabulary are enhanced by exposure to aural language since as early an age as possible [1]. Children spend many hours in acoustic environments where target speech signals are embedded in competing sounds from multiple sources. In these environments, perception of target speech is assisted by a listener's a listener's ability to segregate the multitude of sounds into separate auditory streams, one cue to which is the angle of incidence of different sounds [2]. Children with profound sensorineural hearing loss (SNHL) experience delays in learning to understand the speech of others and to produce intelligible speech. There is solid evidence that moderate (or more severe) hearing impairment exerts a negative impact on speech, language, cognitive development, and early identification and management may be of great benefit to these children, through improved language, communication, mental health, and employment prospects [3]. The use of Hearing Aids (HA) or Cochlear Implantation (CI) can partially or fully restore hearing. Consequently speech production can improve over time and enters the normal range. After hearing is restored, hearing impaired individuals use auditory feedback to adjust voice features such as voice intensity, intonation and vowel duration [4]. When traditional amplification devices (hearing aids) are unable to restore access to the full range of phonemic components of speech, a cochlear implant (CI)

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is a widely used treatment option for children with SNHL [5]. Cochlear Implants (CI) which are called as bionic ears are effective in transmitting salient features of speech, especially in quiet [6]. Because the goal of restored hearing in a deaf child is to enable useful hearing, a key measure of outcome should reflect how a deaf child's experience with a CI develops into the effective use of spoken language. Parental surveys indicate that the outcome of their greatest concern after surgical intervention in children with SNHL is the level of spoken language achieved [7].

Objectives

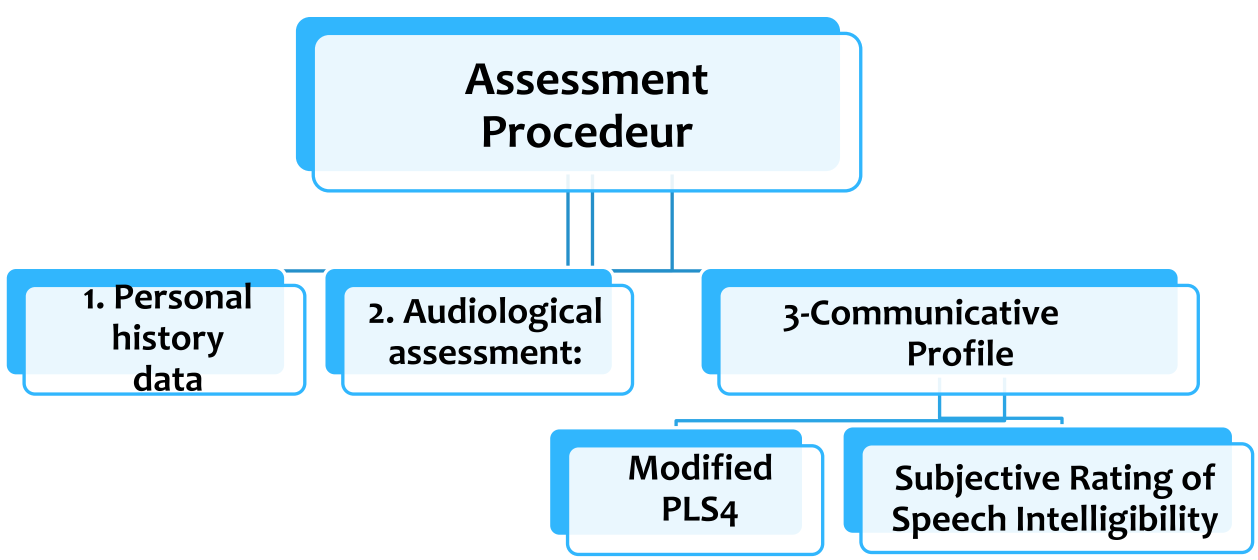
The aim of this study is to compare the functional benefit of the communicative skills of children with CI in relation to those using hearing aid in order to compare the role of each amplification device on the communicative abilities of severe to profound and profound sensorineural hearing impaired children.

Subjects & Methods

This research was conducted during the period between the years 2015 and 2017. The study protocol was approved by the Otolaryngology Department Council of Beni-Suef University. Consent to participate in this research was obtained from the subjects' parents before commencement of the study. This study employed a comprehensive design to examine outcomes in multiple domains of communication in children who used either bilateral behind the ear hearing aids or a unilateral cochlear implant for a period of one year. These were selected from children seeking language rehabilitation in Phoniatrics Unit, Beni-Suef University Hospital. Shortly after confirmation of bilateral permanent hearing loss, all children were typically fitted with bilateral behind the ear hearing aids using the desired sensation level (DSL) prescription method. When hearing aids were deemed to be inadequate and when language development was poor after one year of regular rehabilitation, children underwent a comprehensive team evaluation for cochlear implant candidacy and received unilateral cochlear implants. All children received audiologic management and preschool rehabilitation and all children were enrolled in rehabilitation programs with a focus on the development of receptive &expressive language. Children were regular in Phoniatrics clinic, were asked to follow up auditory rehabilitation & language therapy program twice per week. Children with cochlear implants were followed every month for mapping of their speech processor and speech recognition testing. The study received ethical approval from the Hospital of Beni-suef University and written informed consent was obtained from all their parents. Collaboration between ENT clinic, Audiology clinic& Phoniatrics clinic was done in the form of ENT examination, audiological assessment, and language assessment and rehabilitation for all children. This study has a prospective design. It started after fitting all children with bilateral behind the ear hearing aids provided that the primary language assessment before rehabilitation is present in the medical files of these children. A 2nd language assessment was done after 12 months of language therapy to detect the progress of the language development to take the decision either to complete with hearing aids or to decide upon a cochlear implant. Then a 3rd language assessment was done after another 12 months of rehabilitation. These sixty patients were divided into two groups:

- **Group A:** Thirty children, who have used behind the ear hea-ring aids for two year and attended regular language therapy. Those children are not candidates for cochlear implants due to satisfactory progress with the hearing aids.
- **Group B:** Thirty children, who used bilateral behind the ear hea-ring aids and had regular language therapy for one year with poor response, so they shifted to cochlear implantation, and were enrolled in auditory training and language therapy for another year.

All patients were fitted with bilateral powerful digital signal processing BEHAs and used them for at least a 12-months trial period before determination of candidacy. Lack of benefit was determined by lack of progress in the development of simple auditory skills and Language assessment. Hearing aid use was determined by parental and therapist reports. After surgical implantation of the device and an adequate healing period, the implants were activated (usually 4 weeks after surgery). The children were fitted with one of the two brands of speech processors using a behind the ear controller. Speech processors used in this study were OPUS 2 with standard Sonata electrode & Cochlear Freedom Processor with nucleus 24 k straight electrode.



In this study using Modified Preschool Language Scale & Subjective Speech Intelligibility Test gave us a summary of the improvement of these children. This is matched with other studies which focused that both comprehension and expression of spoken language are important markers of parent-perceived success of a CI.

*** Language improvement quotient:**

The language improvement quotient [8] was used to compare between the rates of progress in language in order to overcome the bias of age matching between the individuals in the study.

$$\text{Language improvement} = \frac{\textit{2nd language age-1st langauge age}}{\textit{duration of langauge rehabilitation}}$$

* A_1 refers to language development of group (A) after using bilateral behind the ear hearing aids for 12 months which is calculated by this equation:

$$A_1 = \frac{\textit{2nd language age-1st langauge age}}{\textit{12(duration of rehabiltation)}}$$

* A_2 refers to language development of group (A) after using bilateral behind the ear hearing aids for another 12 months which is calculated by this equation:

$$A_2 = \frac{\textit{3rd language age-2st langauge age}}{\textit{12(duration of rehabiltation)}}$$

* A_3 refers to language development of group (A) after using bilateral behind the ear hearing aids for 24 months which is calculated by this equation:

$$A_3 = \frac{\textit{3rd language age-1st langauge age}}{\textit{24(duration of rehabiltation)}}$$

* B_1 refers to language development of group (B) after using bilateral behind the ear hearing aids for 12 months which is calculated by this equation:

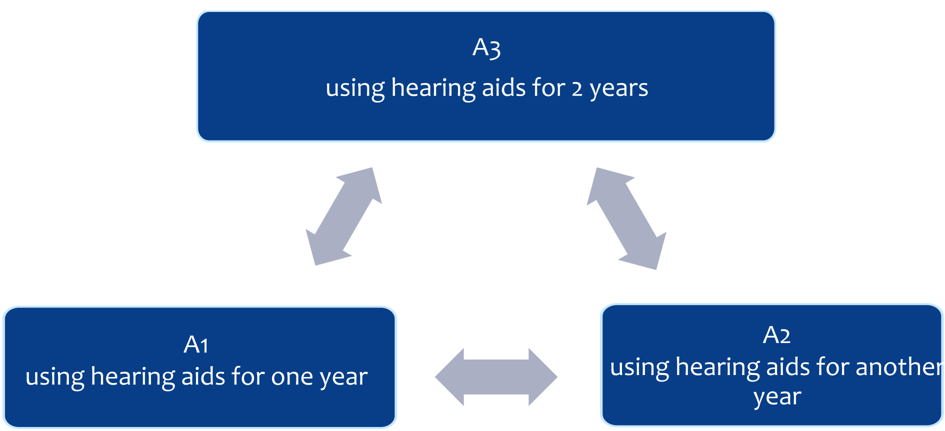
$$B_1 = \frac{\textit{2nd language age-1st langauge age}}{\textit{12(duration of rehabiltation)}}$$

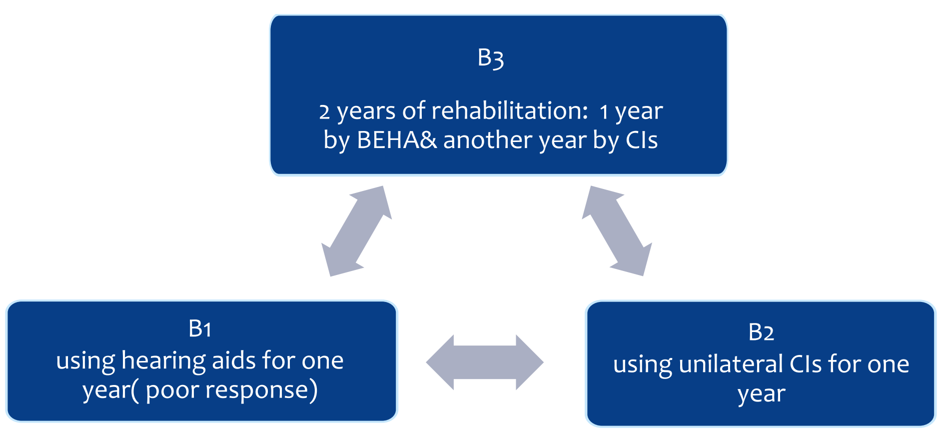
* B_2 refers to language development of group (B) after using unilateral cochlear implant for 12 months which is calculated by this equation:

$$B_2 = \frac{\textit{3rd language age-2st langauge age}}{\textit{12(duration of rehabiltation)}}$$

* B_3 refers to language development of group (B) after using unilateral cochlear implant after 24 months which is calculated by this equation:

$$B_3 = \frac{\textit{3rd language age-1st langauge age}}{\textit{24(duration of rehabiltation)}}$$





Statistical Studies

Data was analyzed using SPSS, Statistical Package for the Social Sciences version 17 (SPSS Inc., Chicago, IL). Numerical data were expressed as mean, standard deviation, and range. For quantitative data, comparison was done using Mann-Whitney test (non-parametric t-test). A p-value < 0.05 was considered significant. Spearman-rho method was used to test correlation between numerical variables (r > 0.3 = no correlation, r = 0.3-0.5 = fair correlation, r = 0.5-0.1 = good correlation).

Results

Group (A) are hearing aids users for 2 consecutive years, Group (B) are Hearing aids users for 1 year followed by CI for another year.

I. **Demographic data of the 2 groups:**

1. Age
2. Gender.
3. Incidence of hearing loss.
4. Psychometric evaluation.
5. Pure tone Audiometry.
6. First language age.
7. Radiology.

1. **Age distribution:** Both groups are matched according to age. In group (A) the age of the children ranged between 3 years and 7years. In group (B). The age of the children ranged Between 3 years& 7 years, provided that all children were implanted before the age of 6 years.
2. **Gender:** No significant difference was noted in gender of both groups.
3. **Incidence of hearing loss:** In group (A) there were 24 children (80%) with congenital hearing impairment And 6 children (20%) with acquired hearing loss, while in group there were 18 children (60%) with congenital hearing impairment and 12 children (40%) With acquired hearing loss.
4. **Psychometric evaluation:** All children in group (A) had normal psychometric evaluation with a mean Value 87.5± 4.6; also in group (B) all children had normal psychometric Evaluation with a mean value 86.4±5.1.
5. **Pure tone results:** Pure tone results of group (A) maintained a mean value of 27.9 dB HL. Group (B). Decreased in mean values from 65.7± 8.2 dB HL in the first year to a mean of 25.2± 2.4 dB HL in the 2nd year. There was a highly significant difference (P=0.001) between group (A) and group (B) in the 1st year in favor of group (A), As well as between both groups in the 2nd year (P=0.001) but in favor of group (B).
6. **First language age:** Before start of therapy, both groups had no passive vocabulary and were Nonverbal. They used either babbling or vocal play.
7. **Radiology:** In group (A) 28 children (93.3%) were having normal CT and MRI of Petrous Bone and only 2 children (6.7%) were having ossification, while in group (B) all Children were having normal CT and MRI of Petrous bone.

Thus both groups were matched regarding age, gender, psychometric Evaluation, language age and cause of H.L (congenital or acquired). However, the aided audiogram was better in group (A).

II. **Progress of both groups in 2 years:**

Paired T test was used to estimate the amount of progress of language skills In 2 years [Figure 1]. Both groups improved highly significantly by the end of the second year.

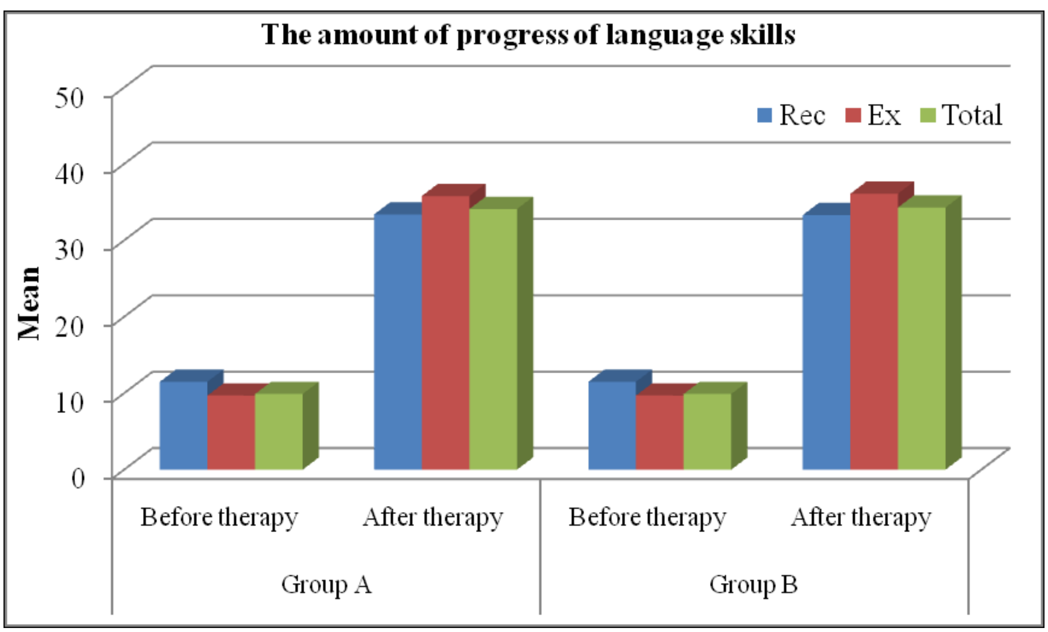


Figure 1: Shows progress between (before therapy) and (after therapy) in both groups regarding receptive, expressive and total language, expressed in language age.

III. Comparison between the 2 groups improvement in the different Durations:

ANOVA and Post Hoc tests were used to compare between the relative Improvement in language skills in each year, in both years; between both Groups. The comparison was done separately for the receptive skills and the Expressive skills, then for the total language age [Tables 1, 2, 3 and Figures 2, 3, 4, 5, 6].

(A1) Represents language improvement quotient in group (A) after the 1st year of Rehabilitation.
(A2) Represents language improvement quotient in group (A) after the 2nd year of Rehabilitation.
(A3) Represents language improvement quotient in group (A) after 2 years of Rehabilitation.
(B1) Represents language improvement quotient in group (B) after the 1st year of Rehabilitation.
(B2) Represents language improvement quotient in group (B) after the 2nd year of Rehabilitation.
(B3) Represents language improvement quotient in group (B) after 2 years of Rehabilitation.

Table 1: Comparison of receptive language improvement quotient among the different durations of therapy in both groups.

	A_1	A_2	A_3	B_1	B_2	B_3
A_1 1.5±0.44	1.05±0.44	0.68±0.39	0.94±0.21	0.17±0.12	1.66±0.37	0.91±0.17
	-	0.001**	0.160	0.001**	0.001**	0.068
A_2 0.68±0.39		-	0.001**	0.001**	0.001**	0.005**
A_3 0.94±0.21			-	0.001**	0.001**	0.669
B_1 0.17±0.12				-	0.001**	0.001**
B_2 1.66±0.37					-	0.001**
B_3 0.91±0.17						-

Table 2: Comparison of expressive language improvement quotient among the different durations of therapy in both groups.

	A_1	A_2	A_3	B_1	B_2	B_3
A_1 0.51±1.04	0.51±1.04	1.70±1.11	1.16±0.35	0.30±0.29	1.97±0.66	1.10±0.31
	-	0.001**	0.001**	0.250	0.001**	0.001**
A_2 1.70±1.11		-	0.004**	0.001**	0.149	0.001**
A_3 1.16±0.35			-	0.001**	0.001**	0.746
B_1 0.30±0.29				-	0.001**	0.001**
B_2 1.97±0.66					-	0.001**
B_3 1.10±0.31						-

Table 3: Comparison of total language improvement quotient among the different durations of therapy in both groups.

	A_1	A_2	A_3	B_1	B_2	B_3
A_1 0.76±0.61	0.76±0.61	1.22±0.79	1.07±0.25	0.21±0.18	1.84±0.46	0.93±0.37
	-	0.001**	0.016*	0.001**	0.001**	0.171
A_2 1.22±1.79		-	0.217	0.001**	0.001**	0.023*
A_3 1.07±0.25			-	0.001**	0.001**	0.291
B_1 0.21±0.18				-	0.001**	0.001**
B_2 1.84±0.46					-	0.001**
B_3 0.93±0.37						-

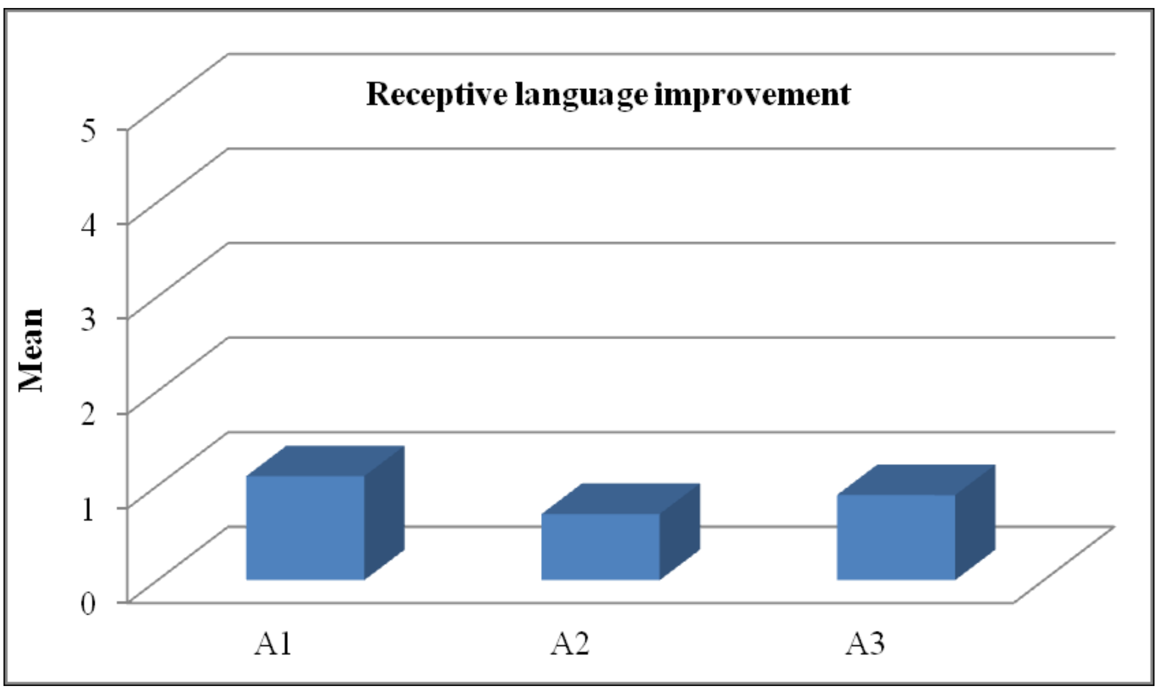


Figure 2: Shows receptive language improvement quotient in A1, A2, and A3.

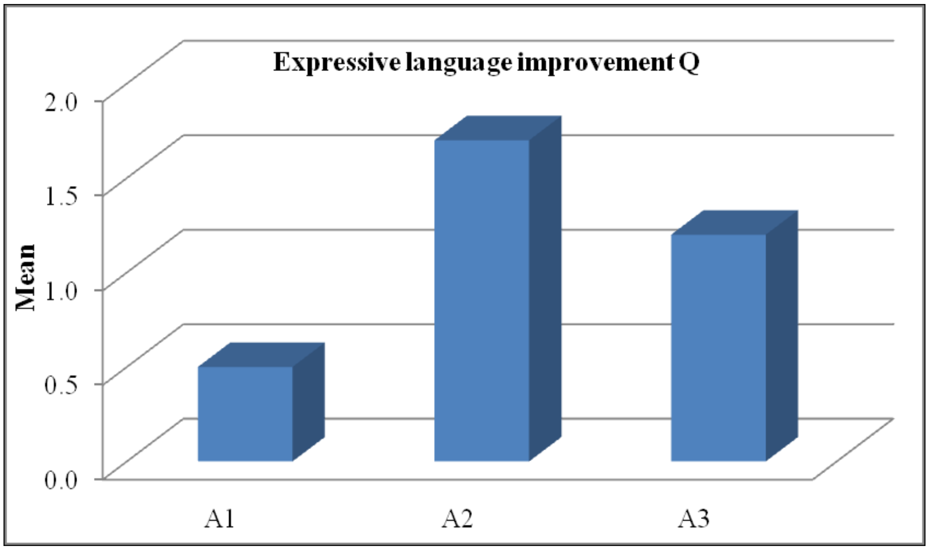


Figure 3: Shows expressive language improvement quotient in A1, A2, and A3.

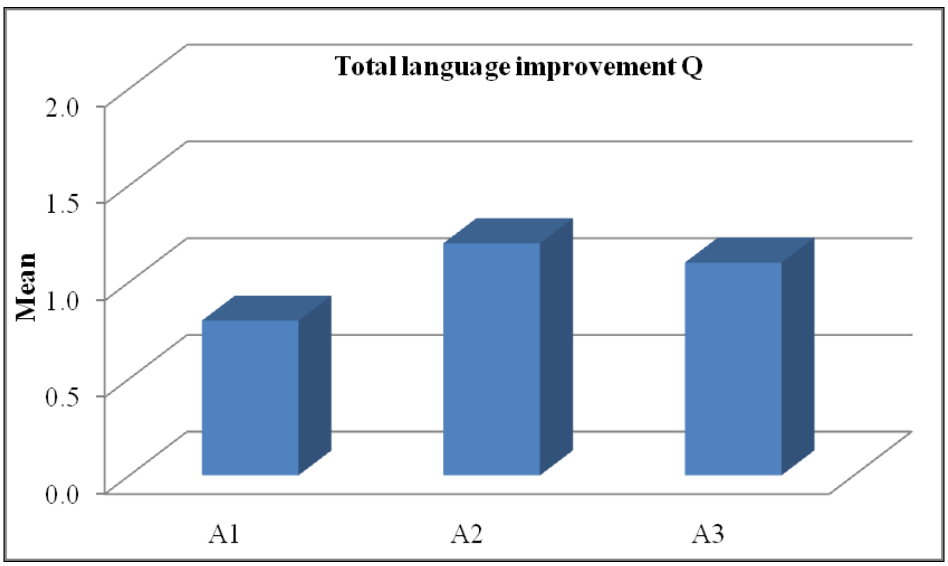


Figure 4(a): Shows total language improvement quotient in A_1, A_2, and A_3.

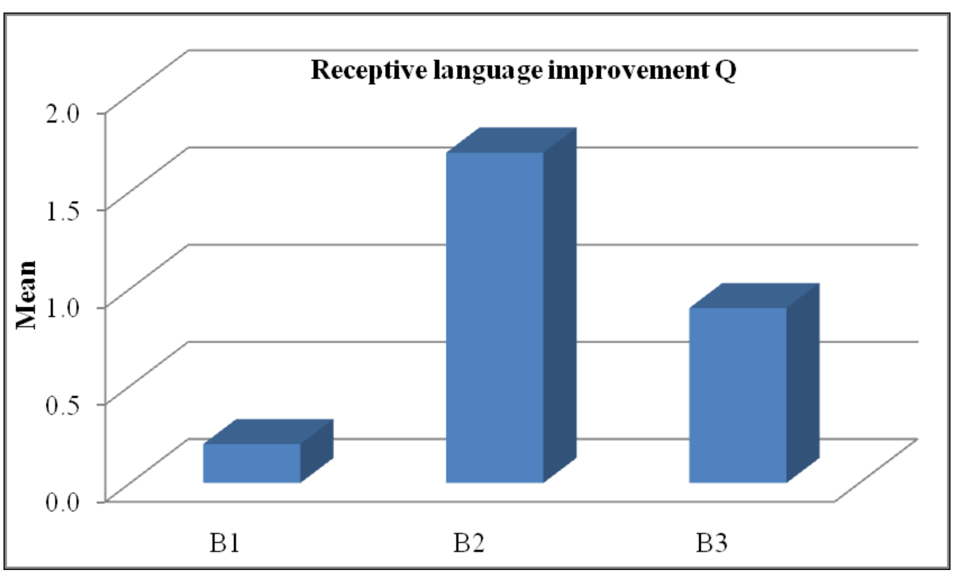


Figure 4(b): Shows receptive language improvement quotient in B_1, B_2, and B_3.

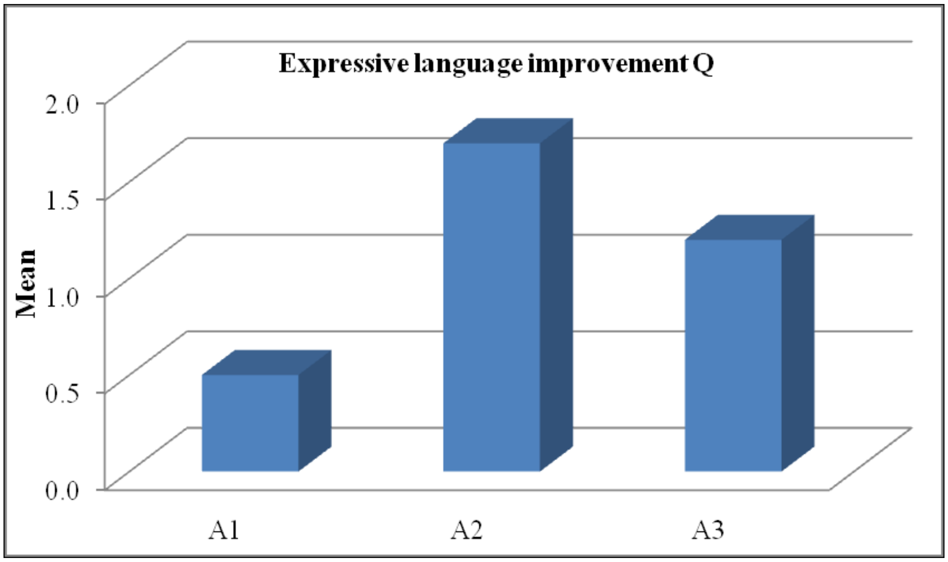


Figure 5: Shows expressive language improvement quotient in B_1, B_2, and B_3.

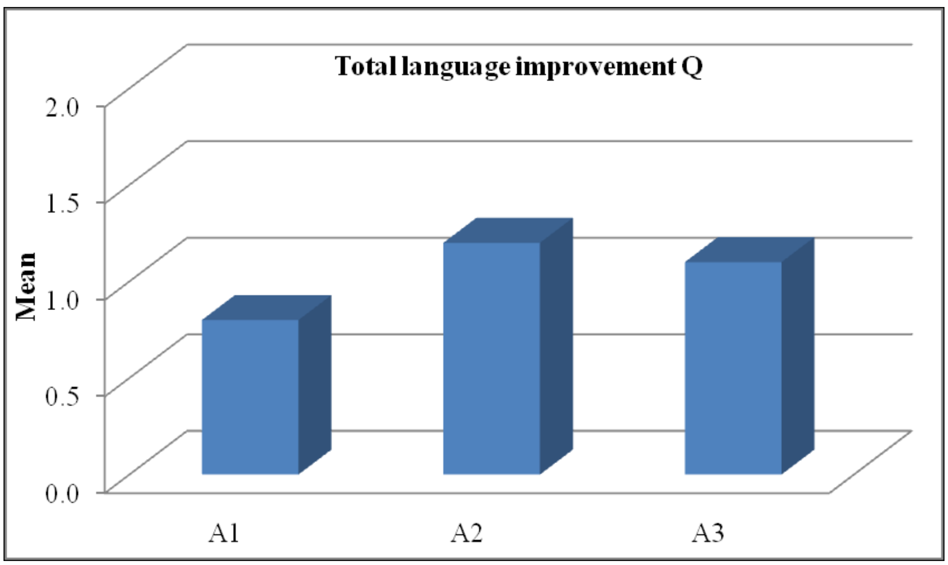


Figure 6: Shows total language improvement quotient in B_1, B_2, and B_3.

Speech intelligibility test:

Subjective Speech Intelligibility Test is composed of 3 assessments, 1st is the Therapist assessment, 2nd is outsider rater & the 3rd is another outsider rater Table 4: Comparison between the mean values of the 3 raters in group (A) And group (B) showed no significant difference.

Table 4: Comparison between group (A) and group (B) regarding mean Of Subjective Speech Intelligibility Test shows no significant difference.

	Group A Mean± SD	Group B Mean± SD	T	P value	Sig.
Mean± SD	3.3±0.1	3.4±0.86	0.63	0.529	NS

Discussion

The primary purpose of this study was to obtain comprehensive data on the development of language and speech skills in a group of permanent hearing impaired children. This group shared the common degree of bilateral hearing impairment (severe to profound or profound hearing impairment), they all sought amplification, and they all sought language rehabilitation after receiving amplification using primarily auditory-based cues. The study aimed also to investigate the difference between the language and speech development under two amplification conditions; bilateral behind the ear hearing aids and unilateral cochlear implants. The choice of language age deficit to compare language skills development among the studied groups is justified by the fact that three variables usually co-vary when language results are analyzed in children; age of use of the amplification device whether hearing aid (HAs) or cochlear implant (CI), the language age before start of rehabilitation, and the age of children at the time of evaluation. The difference in ages at evaluation places the younger children at a maturational and developmental disadvantage in comparison with their older peers. Thus analyzing the results in terms of language age scores might put the younger group at a disadvantage. At the same time, analyzing the results in terms of language age deficits, although more reasonable, but still, in theory, puts the older group at a disadvantage because of the impact of their ages giving higher values for the deficit from the scored language age. That's why the hypotheses of using the language improvement quotient [8] after determining the exact language age, may be more realistic and less biased by the chronological age differences at the time of evaluation. In this study using Modified Preschool Language Scale & Subjective Speech Intelligibility Test gave us a summary of the improvement of these children. This is matched with other studies which focused that both comprehension and expression of spoken language are important markers of parent-perceived success of a CI [9]. Also proved that speech recognition, a direct measure of the auditory benefit of the cochlear implant. A perfect model for comparing the results of both devices may be practically impossible, given the current indications of cochlear implant use. Severe to profound and profound SNHL children are prescribed CI when they show no auditory or communicative benefit from their hearing aids after using it for a period of at least 6 months under (re)habilitation. This period usually extends to one year during which they get access to the implantation passing across the insurance regulations and fund raising facilities [10]. Reported differences in agreement on candidacy decisions for children with border line audiologic profiles. Investigators have examined the question of benefits by attempting to establish an equivalent hearing level to describe the performance of children with cochlear implants. In this study the decision of implantation was taken in accordance with Food and Drug Association (FDA) Labeled Indications [11]. The decision for implantation follows other studies which indicate that when traditional amplification devices (HAs) are unable to restore access to the full range of phonemic components of speech, a CI is a widely used treatment option for children with SNHL [12]. In this study, which was applied on two groups with comparable ages, a comparison was made between the outcomes of the 2 devices along a period of (re)habilitation of one year in their course of therapy which was followed up for two years. In general, the two groups improved after two years of habilitation in a highly significant manner [Table 6 and Figure 5]. It is coincidental that the average performance of the CI and HA groups within 2 years of habilitation turned out to be so close to one another. If there had been a large difference in performance in favor of the HA group, it would indicate that some children who may have been better off with a hearing aid had been implanted. Conversely, if the CI group were doing better than the HA group, it would indicate that the selection criteria were too conservative and some of the HA users might be better off with a CI. This raises the suspicion of the fact that HA users plateau after a period of progress or at least their progress continue at a less pace. Cochlear implants may have a superior effect on the acoustic environment of children more than hearing aids. During the 90s of the last century, and using the early models of speech processes, studies proved that CI users gained better results than HA users in language and perception skills [13-17] and [18].The minimum age for implantation has progressively reduced [19]. Advantages of cochlear implants over hearing aids extended also the adult population [15]. On the other hand, and according to [20], there is no significant difference in the ability to understand speech in silent or noisy conditions between younger and older cochlear implant users ($p < 0.05$). The author observed fewer cases of depression among older cochlear implant users and of loneliness in both older and younger subjects. Older cochlear implant users were not more depressed or lonely than their counterparts with mild to moderate hearing loss who used conventional hearing aids. Assuming that conventional hearing aid users would have better musical perception skills than cochlear implant individuals. In a study by [21], they found CIs and children with HAs, aged 4 to 5 years, did not differ significantly on language abilities although there were differences in articulation skills in favor of the CI users. Similarly, [22] reported that on average, scores on speech perception, speech production, and language were very similar for a group of 40 children with a mean hearing loss of 78 dB HL who used hearing aids and 47 children with a mean loss of 106 dB HL who used cochlear implants. The two groups obtained similar scores on several open set speech recognition word and sentence tests that are commonly used in cochlear implant candidacy evaluations. Advances in sound processors and related software have enhanced the fidelity with which complex sounds are processed into physiologically meaningful codes [23]. This study pointed to the importance of conducting comprehensive assessments when evaluating whether a child with severe to profound sensory neural hearing loss would likely derive greater benefit from a cochlear implant compared to a hearing aid. Given the progress in technology, it is important to continue documenting the benefits of both management options to ensure that children have access to optimal care to permit both parents and physicians to make decisions informed by the best available evidence.

Conclusion

1. CI children showed better rate of language acquisition skills along a one-year use of the implant compared to a similar period of HA in the same children and in another group of HA users.
2. A multifaceted and long-term assessment protocol is needed to draw more realistic judgments on the benefits of each device and its effect on children's achievements.

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