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ORIGINAL ARTICLE

ASSESSMENT OF IMPROVEMENT IN SPEECH PERCEPTION AND LANGUAGE DEVELOPMENT IN COCHLEAR IMPLANT SURGERY: AN INTERESTING STUDY FROM A TERTIARY CARE HOSPITAL OF CENTRAL INDIA

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ABSTRACT: Severe to profound prelingual deafness that is either congenital or acquired is estimated to occur in 0.5 to 3 per 1000 live births. This is often associated with early delays in language development, speech perception, socialization and results in lower academic achievement. These developmental and behavioral problems are severe as 90 % of children are born to normal patients whereas with deaf parents it is less as they have a mutual communication. After much research in this field the first 22 channel cochlear implant surgery was done in 1982. The number of prelingually deafened adults seeking cochlear implant is increasing as these individuals can derive substantial benefit, although their performance is poorer than adults with post-lingual deafness. **MATERIAL AND METHODS:** The present prospective study was conducted in the Department of ENT, Pt. J.N.M. Medical College and Dr. B.R.A.M. Hospital, Raipur (C.G.) The subject selected were prelingually deafened individuals who were undergoing post cochlear implant speech therapy in the Department. This study included individuals, who underwent cochlear implant surgery in this Department during the period of July, 2008 to September, 2010 and the age was within 10 years at the time of surgery. The study was designed as a prospective longitudinal analysis to asses functioning of patients, who underwent cochlear implantation. A total 37 cochlear implant surgeries were carried out in Department. Of these 3 cases were outside the age criteria of the present study and another 2 cases were lost in follow up. Pre-operatively, detailed information of subject including the age, sex and address as well as contact number was collected. Then a General Examination was followed with reference to Built, Nutrition, Pulse, and Blood pressure, Oedema, Cyanosis, Clubbing and Citrus. A systemic examination was also performed. A Local Examination with special emphasis to tympanic membrane and any middle ear pathology was carried out. All the children were investigated for routine blood, urine tests and a chest x-ray. Audiological and Radiological Evaluation was done. Speech perception and language development was also assessed by using standardized tests. Language quotient (Language age/chronological age) was calculated. **RESULT:** A total 327 children of 1 to 10 years of age with prelingual deafness came in ENT OPD. Number of male child (169) was slightly more than the female child (158). The ratio of male and female children included in the present study was 1:1. There was statistically significant increase in Ling 6 sound score from pre-operative (Mean=15.22, Standard Deviation=22.05) to third month after switch on (N=32) [Mean=56, Standard Deviation=22.36, $t(31)=10.87$, $p<0.05$]. The eta squared statistic (0.79) indicated a large effect size. There was also a significant increase in Ling 6 sound score at sixth month after switch on (N=18) [Mean=68.94, Standard Deviation=21.28, $t(17)=12.19$, $p<0.05$] than the preoperative score (Mean=6.11, Standard Deviation= 14.15). The eta squared statistic (0.9) indicated a large effect size. The mean increase in Hindi PB word score was significantly less in children with delayed development (Mean=1.67, Standard deviation=4.08) than those without any delayed

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development [Mean=14.85, Standard deviation=13.69, t(30)=2.30, p (0.03)<0.05] at 3rd follow up month. The eta squared value (0.15) showed a large effect size. The mean increase in receptive language quotient score was significantly more in children without any delay in development (Mean=0.08, Standard deviation=0.13) than those children with a delayed development [Mean= 0.03, Standard deviation= 0.03, t(29.90) 3.87, p(0.001) <0.05] at 3rd follow up month. The eta squared value (0.32) showed a large effect size. Regarding expressive language development quotient there was a decrease in the score after 3 months in group with a delayed development. The mean increase in expressive language quotient score was significantly more in children without any delay in development. At 6 months after switch on the increase in Hindi PB word score was significantly better in those who had their hearing aid before 2 years of age (Mean=20, Standard deviation=11.73) than those who had hearing aid in a later age [Mean=9.23, Standard deviation=7.02, t(16)=2.42, p(0.028)<0.05]. For Receptive Language Quotient score there was also no significant difference in mean increase in score after three months of switch on for Group A and Group B.
CONCLUSION: Children with delayed development are performed out by their normal peers. Yet, these children with a delay in development also show improvement in speech perception after cochlear implantation. Use of early conventional amplification leads to a better speech perception outcome and this, most likely, is also true for language development.
KEYWORDS: Prelingual deafness, Cochlear implant, Speech Perception, Language Development.

INTRODUCTION: Severe to profound prelingual deafness that is either congenital or acquired is estimated to occur in 0.5 to 3 per 1000 live births[1]. This is often associated with early delays in language development, speech perception, socialization and results in lower academic achievement. These developmental and behavioral problems are severe as 90 % of children are born to normal patients whereas with deaf parents it is less as they have a mutual communication.[1] A cochlear implant is a small, complex electronic device that provides a sense of sound to a person who have severe (Speech perception thresholds of 75-90 dB) to profound (Speech perception threshold of >91) sensorineural hearing loss, and do not benefit from powerful hearing aids which only amplify sounds.[2] A cochlear implant, on the other hand, is designed to convert the mechanical sound into an electrical impulse which stimulates the auditory nerve causing the sensation of sound and helps a deaf person to understand speech. In 1957, the first research on cochlear implant began in France. Published studies of electrical stimulation of the auditory nerve date back half a century, but Dr. William House first introduced the single channel cochlear implant only about 30 years back, when it met with great skepticism.[2]

After much research in this field the first 22 channel cochlear implant surgery was done in 1982. The number of prelingually deafened adults seeking cochlear implant is increasing as these individuals can derive substantial benefit, although their performance is poorer than adults with post-lingual deafness.[3] the ideal prelingually deaf adults are those with consistent hearing aid use, preferably with some residual hearing, and who use oral communication. Till date around 2, 00,000 people world-wide have received cochlear implants and the number is growing rapidly.[3] The present work is undertaken in an endeavor to assess the speech perception and language development after cochlear implant surgery and to evaluate the role of certain factors in this outcome. In present study, speech perception and language development will be assessed both preoperatively and postoperatively. For speech perception, Ling-6-sound test and Phonetically Balanced Hindi Open Set Words test will be applied according to the child's age and cognitive ability.

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The language part will be assessed by a Language development scale. This study will evaluate the factors for better speech and language development after cochlear implant surgery thus helps in a better rehabilitation of the children in terms of communication, social and academic functioning.

MATERIAL AND METHODS: The present prospective study was conducted in the Department of ENT, Pt. J.N.M. Medical College and Dr. B.R.A.M. Hospital, Raipur (C.G.) The subject selected were prelingually deafened individuals who were undergoing postcochlear implant speech therapy in the Department. Our study included individuals, who underwent cochlear implant surgery in this Department during the period of July, 2008 to September, 2010 and the age was within 10 years at the time of surgery. The study was designed as a prospective longitudinal analysis to asses functioning of patients, who underwent cochlear implantation.

Selection Criteria:

The subject in the present study was included according to following criteria:

1. Children who had operated for cochlear implantation surgery in the Department of E.N.T., Dr. B.R.A.M. Hospital.
2. Children undergoing pre and post cochlear implant auditory verbal therapy in the Department of E.N.T., Dr. B.R.A.M. Hospital.
3. Prelingually deaf.
4. Age 1 to 10 years at the time of surgery.

From July, 2008 to September, 2010 a total 37 cochlear implant surgeries were carried out in Department of Otorhinolaryngology, Dr. B.R.A.M. Hospital. Of these 3 cases were outside the age criteria of the present study and another 2 cases were lost in follow up.

Pre-operatively, detailed information of subject including the age, sex and address as well as contact number was collected. The following points had specially being addressed while history was taken from parents:

1. Age of onset of hearing impairment as well as age at which a hearing loss first diagnosed.
2. Duration of deafness.
3. Any history of trauma, meningitis, encephalitis, measles, mumps and ototoxic drugs etc.
4. Any associated ear discharge.
5. Any other associated handicap.
6. Regarding antenatal history, any history of CMV, Rubella, Malaria, Toxoplasmosis, German measles and Syphilis etc. during pregnancy was asked. Use of any ototoxic drugs as well as any trauma during pregnancy had also being quarried.
7. In natal history, the time and type of delivery were asked and birth weight was also noted. Parents were specifically asked about any NICU (Neonatal Intensive Care Unit) staying of the newborn or kernicterus or any sort of prolonged ventilation.
8. For post-natal history, history of meningitis or use of any ototoxic drugs was asked.
9. A detailed developmental history was also part of the procedure.
10. Parents were asked for any kind of impaired hearing in their family.
11. Whether the child attends any school or not was asked to the parents.
12. Regarding use of hearing aid, age when hearing aid first used as well as duration and frequency of hearing aid use (i.e. Rarely, sometimes, mostly or always) were also noted.

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Then a General Examination was followed with reference to Built, Nutrition, Pulse, and Blood pressure, Oedema, Cyanosis, Clubbing and Icterus. A systemic examination was also performed. A Local Examination with special emphasis to tympanic membrane and any middle ear pathology was carried out. All the children were investigated for routine blood, urine tests and a chest x-ray. Audiological and Radiological Evaluation was done. Speech perception and language development was also assessed by using standardized tests. Language quotient (Language age/chronological age) was calculated. Data was compiled in MS excel and checked for its completeness, correctness and then it was analyzed. Suitable statistical test was applied and p value<0.05 was considered as a statistical significant.

RESULT: A total 327 children of 1 to 10 years of age with prelingual deafness came in ENT OPD of Dr. B.R.A.M. Hospital during the study period. Number of male child (169) was slightly more than the female child (158). The ratio of male and female children included in the present study was 1:1. [Table-1]

There was statistically significant increase in Ling 6 sound score from pre-operative (Mean= 15.22, Standard Deviation=22.05) to third month after switch on (N=32) [Mean=56, Standard Deviation=22.36, t(31)=10.87, p<0.05]. The eta squared statistic (0.79) indicated a large effect size.

There was also a significant increase in Ling 6 sound score at sixth month after switch on (N=18) [Mean=68.94, Standard Deviation= 21.28, t(17)=12.19, p< 0.05] than the preoperative score (Mean= 6.11, Standard Deviation=14.15). The eta squared statistic (0.9) indicated a large effect size. For Phonetically Balanced Open Set Hindi Word Test we also found a statistically significant increase in score from pre-operative (Mean=00, Standard Deviation= 00) to Third month after switch on [Mean=12.38, Standard Deviation=13.46, t(31)=5.20, p<0.05]. The eta squared statistic (0.47) indicated a large effect size. With further follow up we found a significant increase in the score of PB Open Set Hindi Word Test at sixth month (N=18) [Mean=12.22, Standard Deviation=9.58, t(17)=5.41, p<0.05] than the pre-operative value (Mean= 00, Standard Deviation=00).

The eta squared statistic (0.63) indicated a large effect size. Present study was indicating that that the score for Ling 6 sound test and PB Open Set Hindi Word Test after cochlear implantation was continue to increase with time.

In this study we also found a significant increase in Receptive Language Quotient Score from pre-operative to three months after the switch on. A paired samples t-test was done for this. There was statistically significant increase in Receptive Language Quotient Score from pre-operative (Mean=0.29, Standard Deviation=0.15) to third follow up month [Mean=0.35, Standard Deviation=0.18, t (31)=2.82, p (.008)<0.05].

The eta squared statistic (0.20) indicated a large effect size. Moreover the Receptive Language Quotient Score was continued to improve over time.

The mean score of Expressive Language Quotient in the pre-operative period (Mean=0.22, Standard Deviation=0.11) was less than the mean score in third month of follow up (Mean=0.24, Standard Deviation=0.13). However there was no significant increase as the p value (0.18) was more than the alpha value (0.05). The expressive language quotient score continued to improve with time [after six months of switch on

N=18, Mean=0.27, Standard Deviation=0.19]. [Table-2]

The increase in Ling 6 sound score three months after switch on (N=32) was significantly more in children who were implanted at ≤3 years (Mean=53.17, Standard deviation=18.25) than

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those who were implanted at >3 years of age [Mean=33.35, Standard deviation=19.68, t (30)=2.83, p (.008)<0.05]. The magnitude of the differences in the means was large (eta squared=0.21). Again at six months after switch on (N=18) the increase in Ling six sound score was still significantly more in those children who were implanted at age ≤3 years (Mean=78.71, Standard deviation=14.45) than those who were implanted at >3 years of age [Mean=52.73, Standard deviation=19.96, t (16)=2.97, p(.009) <0.05]. The magnitude of differences in the means was large (eta squared=0.35).

For Hindi PB word test, the increase in score after 6months from switch on (N=18) was significantly more in children who were implanted at ≤3years of age (Mean=19.28, Standard deviation=9.76) than those who had their implant at >3 years of age [Mean=7.73, Standard deviation=6.47, t(16)=3.04, p(.008) < 0.05]. The eta squared statistic (0.36) indicated a large effect size. At 3rd month of follow up the mean increase (Mean=53.17, Standard deviation=18.25) of Hindi PB word score in children who were implanted at ≤3 years of age was more than those children implanted >3 years of age (Mean=33.35, Standard deviation=19.68). However the difference was not significant. Regarding receptive language development the mean increase in receptive language quotient in children who had their implantation done at ≤3 years of age (At 3rdMonth of follow up: Mean=0.11, Standard deviation=0.16; at 6th month of follow up: Mean=0.11, Standard deviation=0.10), was more than the other group (At 3rd month of follow up: Mean=0.03, Standard deviation=0.09; and at 6th month of follow up: Mean=0.02, Standard deviation=0.06). But these differences were not significant.

According to the above table the mean increase in expressive language quotient in children who had their implantation done in ≤3 years of age (At 3rd month of follow up: Mean=0.02, Standard deviation=0.10; at 6th month of follow up: Mean=0.09, Standard deviation=0.20), was more than the other group (at 3rd month of follow up: Mean=0.02, Standard deviation=0.05; and at 6th month of follow up: Mean=0.01,

Standard deviation=0.03). However there was no significant difference. [Table-3]

The mean increase in Hindi PB word score was significantly less in children with delayed development (Mean=1.67, Standard deviation=4.08) than those without any delayed development [Mean=14.85, Standard deviation=13.69, t(30)=2.30, p (0.03)<0.05] at 3rd follow up month. The eta squared value (0.15) showed a large effect size.

The mean increase in receptive language quotient score was significantly more in children without any delay in development (Mean=0.08, Standard deviation=0.13) than those children with a delayed development [Mean=0.03, Standard deviation=0.03, t(29.90)=3.87, p(0.001) <0.05] at 3rd follow up month. The eta squared value (0.32) showed a large effect size.

Regarding expressive language development quotient there was a decrease in the score after 3 months in group with a delayed development. The mean increase in expressive language quotient score was significantly more in children without any delay in development (Mean=0.03, Standard deviation=0.08) than those children with a delayed development who actually showed a decrease in the score after 3months of switch on [Mean=-0.02, Standard deviation=0.03, t(24.18)=2.53, p(0.02)< 0.05]. The eta squared value (0.17) showed a large effect size. However in the present study we did not find any significant difference in the mean increase in Ling 6 sound score among the two groups at 3 months of follow up. [Table-4]

An independent samples t test was conducted to compare the increase in speech perception tests and language quotient score in children who had their hearing aid at 2 years of age and who had hearing aid at ≥2 years of age.

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At 3rd month of follow up the increase in Ling 6 sound test score was significantly more in children who had their hearing aid before 2 years of age (Mean=52.60, Standard deviation=16.77) than those who had it at a later age [Mean=35.41, Standard deviation=21.16, t(30)=2.26, p(0.02)<0.05]. The eta squared value (0.14) suggests a large effect size.

Again after 6 months of switch on the increase in Ling 6 sound test score was significantly more in children who had their hearing aid before 2 years of age (Mean=86, Standard deviation=8.94) than those who had it at a later age [Mean=9.82, Standard deviation=9.62, t(16)=3.67, p(0.002)<0.05]. A large effect size was present as eta squared value was 0.46.

At 6 months after switch on the increase in Hindi PB word score was significantly better in those who had their hearing aid before 2 years of age (Mean=20, Standard deviation=11.73) than those who had hearing aid in a later age [Mean=9.23, Standard deviation=7.02, t(16)=2.42, p(0.028) <0.05]. The eta squared value (0.27) suggests a large effect size. The increase of mean score in receptive and expressive

Language quotient, three and six months after switch on, was more in those who received their hearing aid less than 2 years of age. However the difference was not statistically significant. [Table-5]

An independent-samples t-test was conducted to compare the speech perception and language development outcome among children who did not have any exposure to a spoken language other than Hindi (Group A) with those who had the exposure (Group B). Three months after switch on there was no significant difference in increase in Ling 6 sound mean scores for Group A (Mean=41.03, Standard deviation=20.88) and Group B [Mean=38.33, Standard deviation=29.53; t (30)=0.21, p=0.838>0.05]. The magnitude of the differences in the means was very small (eta squared=0.001). As Hindi PB word score was concerned there was also no significant difference in increase in mean score after 3 months of switch on for Group A (Mean=12.45, Standard deviation=13.75) and Group B [Mean=11.67, Standard deviation=12.58; t(30)=0.09, p=0.926>0.05]. The magnitude of the differences in the means was very small (eta squared=0.0002).

For Receptive Language Quotient score there was also no significant difference after three months of switch on for Group A (Mean=0.07, Standard deviation=0.13) and Group B [Mean=0.03, Standard deviation=0.07; t(30)=1.36, p=0.183>0.05]. Eta squared value (0.05) suggests a small effect. Again for Expressive Language Quotient score there was no significant difference after three months of switch on for Group A (Mean=0.02, Standard deviation=0.08) and Group B [Mean=00, Standard deviation=0.05; t(30)=0.52, p=0.608>0.05]. The magnitude of the differences in the means was very small (eta squared=0.009). [Table-6]

Three months after switch on there was no significant difference in increase in Ling 6 sound scores for Group A and Group B. The magnitude of the differences in the means was small (eta squared=0.02). As Hindi PB word score was concerned there was no significant difference in increase in score after 3 months of switch on for Group A and Group B. The magnitude of the differences in the means was very small (eta squared=0.008).

For Receptive Language Quotient score there was also no significant difference in mean increase in score after three months of switch on for Group A and Group B. Eta squared value (0.02) suggests a small effect. Again for Expressive Language Quotient score there was no significant

Difference after three months of switch on for Group A (Mean increase in score=00, Standard deviation=0.07) and Group B [Mean increase in score=0.02, Standard deviation=0.07; t(30)=0.62, p=0.538>0.05]. The magnitude of the differences in the means was small (eta squared=0.01). [Table-7]

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DISCUSSION: Currently, FDA approved deaf babies as young as 12 months of age for cochlear implantation. In emergency situations, where the integrity of the cochlea is in danger due to ossification, infants younger than one year of age have been successfully implanted but it is quite difficult on the part of the parent and the clinician. Hence researchers have attempted to discover: the advantages and disadvantages of early implantation as compared to later implanted children and how early the implantation should occur. In the study Geers, Nicholas and Sedey (2003) found that half of the children who were implanted before 5 years of age reached receptive and expressive language levels that were on par with the average scores of normally hearing peers 4 to 7 years following implantation.[4,5] Svirsky et al. (2004) opines that implantation before the age of 2 resulted in speech perception and language advantages that were significant both from a statistical and a practical point of view.[6]

Moog et al. also found that the majority of elementary school-aged children who were implanted early, scored within the normal range for language and reading.[7] Margaret B. Pulsifer, Cynthia F. Salorio, John K. Niparko (2003) found that greater benefits in audiological and developmental functioning were associated with younger age (<48 months) at implantation.[8] In recent study by Connor et al. (2006), where 100 children who had received their CI between 1 to 10 years of age participated, concluded that there is a substantial benefit for both speech and vocabulary outcomes when children receive their implant before the age of 2.5 yrs. The results of our present study, 6 months after the cochlear implant we found that children who were implanted at or before 3 years of age.[9]

Rajput et al. (2003) found a negative correlation between disability score (Higher scores indicating higher level of disability) and receptive language development, more than three years experience in using the cochlear implant.[10] Spencer (2004) indicated that the cochlear implant was beneficial, but progress was slower than is usually expected from comparable non-multiply disabled implant users.[11] Edwards et al. (2006) in their study on developmental delay and outcomes in paediatric cochlear implantation concluded that significant developmental delay is predictive of poor outcomes, but children with a mild delay do make appreciable progress.[12]

Although congenitally deaf children with a profound hearing loss are almost completely deprived of meaningful sound until implantation, Spencer (2004) found that auditory experience provided by hearing aids before implantation could significantly affect post-implant performance. The children in the study who received early amplification were found to score better on all tests of language and speech after implantation.[13] Children, in our present study, who had received their hearing aid at less than 2 years of age had a significantly better speech perception outcome after three months and six months of post-operative auditory verbal therapy.

India is a country where multiple spoken languages in different regions of the country. In our institution, the auditory verbal therapy was conducted exclusively in Hindi. Three children in present study came from families where the primary spoken language was not Hindi. One child was Bengali, one Malayali, and one child was Tamilian. In these situations, children will typically learn their parents' first language, as well as the national language. All these children were given the same auditory verbal habilitation based on Hindi language. Waltzman et al. (2003) felt that the development of other oral languages in addition to the child's primary language would not impair their ability to communicate in their first language, regardless of cochlear implantation.

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Arnoldner et al. (2004) reported on three cases of Mondini deformity and stated that results are similar to those in children with normal cochlea.[14] The results from a study of 14 adults and 9 children with LVAS (Miyamoto et al. (2002) indicated positive outcomes for both children and adults with auditory and speech recognition performance that did not differ significantly from control subjects.[14] An important anomaly to recognise is the narrow or very narrow internal meatus, which may be demonstrated on CT or MR imaging. Valvassori (1995) drew attention to the fact that a narrow IAC of 2 mm or less is associated with absence of the cochlear nerve.[15] According to Papsin et al.(2005) there was no definite evidence that minor anomalies (Mondini dysplasia or enlarged vestibular aqueduct) are associated with the hearing prognosis.[16] In our present study also we came across children with various types of inner ear anomalies like, Mondini deformity, hypoplastic cochlea, dilated vestibule, isolated large vestibular aqueduct and dysplastic semicircular canal. We attempted to compare the speech perception and language development outcomes in children who had an abnormal MRI with those who had completely normal finding in MRI. After 3months of speech training, the difference in the mean increase in Ling 6 sound score [abnormal MRI=38.78(21.61) normal MRI=45.89(20.50)] and Hindi PB word score [abnormal MRI=13.13(14.31) normal MRI=10.44(11.53)] was not significant between the two groups. The eta squared value was suggestive of a small effect size. As far as the language development was concerned, the mean increase in receptive language quotient [normal MRI=0.03(0.10) abnormal MRI=0.07(0.13)] and expressive language quotient score [normal MRI=00(0.07) abnormal MRI=0.02(0.07)] after 3 months of switch on was not significantly different in the two groups According to eta squared value the magnitude of differences in the means was small.

CONCLUSION: On the basis of observation and analysis of data the following conclusion can be drawn from the present study:

1. After 6 months of post-operative auditory verbal therapy the speech perception significantly increases and moreover, it continues to improve with time. The language development also improves from the pre-operative state and it also shows further improvement with time.
2. Those who are implanted early (At or less than 3 years of age) have a better outcome in respect of speech perception and language development.
3. Children with delayed development are performed out by their normal peers. Yet, these children with a delay in development also show improvement in speech perception after cochlear implantation.
4. Use of early conventional amplification leads to a better speech perception outcome and this, most likely, is also true for language development.
5. Unfortunately the late diagnosis of hearing deprivation and later initiation of conventional amplification with hearing aids are adversary to a good outcome. Proper implication of “Universal neonatal hearing screening” and awareness among the parents will help to overcome these problems.
6. Bilingual children achieve the same benefit in speech perception and language development after cochlear implantation as their monolingual counterpart do.
7. Finally, further analysis of speech perception and language development in larger group of cochlear implanted children for a period of not less than 3 years will be required to establish the long term outcome after cochlear implant surgery.

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Sl. No.	Parameter	Male	Female	Total
1.	Number of Prelingually deaf children of 1 to 10 years of age who attended ENT OPD	169	158	327
2.	Study subject	16	16	32

Table 1: Background characteristics of the study subjects

		Ling 6 Sound Test				Hindi PB Word Test				Language Quotient							
		Mean	SD	Df	T	Mean	SD	Df	T	Mean	SD	Df	T	Mean	SD	Df	t
Pre op vs. after switch on (N=32)	Pre-operative	15.22	22.05	31	10.87	00	00	31	5.20	0.29	0.15	31	2.82	0.22	0.11	31	1.38
	3 m. after switch on	56	22.36			12.38	13.46			0.35	0.18			0.24	0.13		
Pre op vs. 6 months after switch on (N=18)	Pre-operative	6.11	14.15	17	12.19	00	00	17	5.41	0.34	0.17	17	1.77	0.23	0.14	17	1.36
	6 m. after switch on	68.94	21.28			12.22	9.58			0.40	0.21			0.27	0.19		

Table 2: Comparison of speech perception and language development in preoperative period vs. 3 Months and 6 months after switch on (Result of paired samples t-test)

M=months; SD= Standard Deviation; df=degree of freedom

	Age at CI	Ling 6 sound test				Hindi PB word test				Language Quotient							
		Mean	SD	df	t	mean	SD	Df	t	Mean	SD	Df	T	Mean	SD	Df	t
Increase Months after switch on (N=32)	<3yrs (N1=12)	53.17	18.25	30	2.83	14.17	11.45	30	0.58	0.11	0.16	30	1.88	0.02	0.10	30	0.18
	>3yrs (N2=20)	33.35	19.68			11.30	14.71			0.03	0.09			0.02	0.05		
Increase In Score at 6months After switch on (N=18)	<3 yrs (N1=7)	78.71	14.45	16	2.97	19.28	9.76	16	3.04	0.11	0.10	16	1.64	0.09	0.20	16	1.48
	>3yrs (N2=11)	52.73	19.96			7.73	6.47			0.02	0.06			0.01	0.03		

Table 3: Comparison of speech perception and language development outcome in two age at implantation groups (Result of independent samples t-test)

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	Delayed Development (DD)	Ling 6 sound test				Hindi PB word test				Language Quotient							
										Receptive				Expressive			
		Mean	SD	Df	t	Mean	SD	Df	T	Mean	SD	Df	t	Mean	SD	Df	t
Increase months after switch on (N=3)	With DD (N1=6)	38.33	24.83	30	0.30	1.67	4.08	30	2.30	0.03	0.03	29.90*	3.87*	-0.02	0.03	24.18*	2.53 *
	Without DD (N=26)	41.35	20.82			14.85	13.69			0.08	0.13			0.03	0.08		

Table 4:Comparison of speech perception and language development among children with and without delayed development (Result of independent samples t-test)

	Age when HA received	Ling 6 sound test				Hindi PB word test				Language quotient							
		Mean	SD	Df	T	Mean	SD	Df	T	Mean	Sd	Df	T	Mean	SD	Df	t
Increase in score at3 months after switch on (N=32)	<2 years (N2=10)	52.60	16.77	30	2.26	18.00	18.88	11.18*	1.30	0.13	0.17	10.11*	1.74	0.05	0.12	9.56*	1.33
	>2 Years (N2=22)	35.41	21.16			9.82	9.62			0.03	0.07			00	0.03		
Increase in score at 6 months after switch on (N=18)	<2 Years (N1=5)	86.00	8.94	16	3.67	20.00	11.73	16	2.42	0.07	0.18	16	0.33	0.09	0.21	16	1.12
	>2 years (N2=13)	53.92	18.46			9.23	7.02			0.05	0.11			0.02	0.08		

Table 5: Comparison of speech and language development outcome after CI with reference to initial age of hearing aid (HA) fitting (Result of independent samples t-test)

*Levene's test for equality of variance was <0.05 so equal variances not assumed

	Exposure to a spoken language other than Hindi	Ling 6 Sound test				Hindi PB word test				Language Quotient							
										Receptive				expression			
		Mean	SD	df	T	Mean	SD	Df	t	Mean	Sd	Df	T	Mean	Sd	Df	t
Increase in score at 3 months after switch on (N=32)	No (N1=29) (Group A)	41.03	20.88	30	0.21	12.45	13.75	30	0.10	0.07	0.13	30	1.36	0.02	0.08	30	0.52
	Yes (N2=3) (Group B)	38.33	29.53			11.67	12.58			0.03	0.07			00	0.05		

Table 6: Comparison of speech perception and language development outcome after CI with reference to exposure to a spoken language other than Hindi (Result of independent samples t-test)

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	MRI	Ling 6 sound test				Hindi PB word Test				Language Quotient							
		Mean	SD	Df	T	Mean	SD	Df	t	Mean	Sd	Df	t	Mean	SD	Df	t
Increase in score at 3 months after switch on (N=32)	Normal (N1=9) (Group A)	45.89	20.50	30	0.58	10.44	11.53	30	0.50	0.03	0.10	30	0.76	00	0.07	30	0.62
	Abnoramal (N2=23) (Group B)	38.78	21.61	30	0.58	13.13	14.31	30	0.50	0.07	0.13	30	0.76	0.02	0.07	30	0.62

Table 7:Comparison of speech perception and language development outcome after CI with reference to inner ear anomaly in MRI (Result of independent samples t-test)

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