“Overview of cochlear implant results among children in Kuwait”

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Abstract:
The cochlear implant operation presented a wonderful opportunity to those with deep to severe hearing loss from various sources who were not responding to hearing aids. This study examined Kuwait's infant cochlear implant programming and its case outcomes and implementation. Kuwaiti cochlear implant recipients who received speech therapy and device programming were studied.

The study found 177 files on children aged 2001–2013, picked at random for gender and nationality. About 95% of patients had bilateral severe to profound SNHL before surgery. The majority (112) were implanted on the right (63.3%), followed by the left (34.5%) and a tiny number (4.3%) on both sides. Mean age at implantation was 3.86±2.25, statistically significant with a p-value < 0.001. Neither gender nor nationality were statistically significant. Nucleus, MED-EL, and Advanced Bionics devices were used. The greatest percentages were Nucleus 145 (81.9%), Med-El (20.3%), and Advance Bionics (12.8%). After surgery, 51.5% of patients' hearing thresholds were 31–45 dB, 39.8% were 10–30 dB, and 8.7% were over 45 dB in terms of speech discrimination score (SD), 37.1% scored 90% or higher, 13.6% scored 76%–90%, 9.1% scored 61%–75%, 7-8% had distorted speech, and 21.2% were still trilingual.

In conclusion with the results, the Kuwaiti team's 2001 cochlear program proved successful. Families are upended when their children regain speech, finish school, and catch up to their classmates.

Key words: Hearing loss, cochlear implant, age of implant, postoperative hearing threshold level, postoperative speech reception and speech discrimination.

الملخص:

قدمت عملية زراعة القوقعة الصناعية فرصة رائعة لأولئك الذين يعانون من فقدان السمع العميق إلى الشديد من مصادر مختلفة والذين لم يستجيبوا للمعينات السمعية .تناولت هذه الدراسة برمجة زراعة القوقعة الصناعية للأطفال في الكويت ونتائج حالتها وتنفيذها وتمت دراسة متلقي زراعة القوقعة الصناعية الكويتيين الذين تلقوا علاج النطق وبرمجة الأجهزة.

وجدت الدراسة ١٧٧ ملفًا عن أطفال تتراوح أعمارهم بين ٢٠٠١ و٢٠١٣، تم اختيارهم عشوائيًا حسب الجنس والجنسية. حوالي ٩٥% من المرضى كانوا يعانون من SNHL شديد إلى عميق في الجانبين قبل الجراحة. الأغلبية (١١٢) زرعت في الجانب الأيمن (٦٣,٣%)، يليها اليسار (٣٤,٥%) وعدد قليل (٤,٣%) في كلا الجانبين. كان متوسط العمر عند الزرع ٣,٨٦ ± ٢,٢٥، وهو ذو دلالة إحصائية بقيمة .p <0.001 لم يكن الجنس ولا الجنسية ذات دلالة إحصائية. تم استخدام أجهزة Nucleus و MED–ELو .Advanced Bionics وكانت النسب الأكبر هي(Nucleus 145 (81.9% ، و(Med–El (20.3%، و .(Advance Bionics (12.8%بعد الجراحة، كانت عتبات السمع لدى ٥١,٥% من المرضى ٣١–٤٥ ديسيبل، و٣٩,٨% كانت ١٠–٣٠ ديسيبل، و٨,٧% كانت أكثر من ٤٥ ديسيبل. من حيث درجة التمييز في الكلام(SD) ، سجل ٣٧,١% ٩٠% أو أعلى، و١٣,٦% سجل ٧٦%–٩٠%، و٩,١% سجل ٦١%–٧٥%، و٧–٨% كان لديهم خطاب مشوه، و٢١,٢% كانوا لا يزالون يتحدثون ثلاث لغات.

وفي الختام وبالنتائج أثبت برنامج القوقعة الإلكترونية للفريق الكويتي لعام ٢٠٠١ نجاحه. تنقلب العائلات عندما يستعيد أطفالهم القدرة على الكلام، وينهون المدرسة، ويلحقون بزملائهم في الفصل.

الكلمات المفتاحية: فقدان السمع، زراعة القوقعة الصناعية، عمر الزرعة، مستوى عتبة السمع بعد العملية الجراحية، استقبال الكلام بعد العملية الجراحية وتمييز الكلام.

Introduction:

People who have severe to profound hearing loss and cannot benefit from hearing aids can get a sense of hearing again with a cochlear implant, a device that is surgically implanted. Electrical stimulation of the auditory nerve allows a cochlear implant to bypass malfunctioning or underdeveloped cochlear structures, allowing the central auditory nervous system to receive useful information about sound (Dawn Burton Koch, et al, 2004).

The pioneering pediatric cochlear implant program began in 1980 at the House Ear Institute. As unbelievable as it seems now, the main concern back then was whether or not to even think about having children implanted.

A nine-year-old boy was the first kid to get a cochlear implant in 1980, and by 1982, twelve children ranging in age from three and a half to seventeen had received the technology (Laurie S. Eisenberg, et al., 2006, Dawn Burton Koch, et al., 2004).

The FDA approved the House/3M device for use in adults in 1984 and in children in 1986 for implantation. The Food and Drug Administration (FDA) authorized the Nucleus-22 channel implant for use in children older than two years old in June 1990. Rapid adoption of the practice followed shortly after, and by the mid-1990s, the number of youngsters implanted had surpassed that of adults (Dawn Burton Koch, et al., 2004).

Historically, the Food and Drug Administration (FDA), a consumer and health protection organization in the United States, had substantial influence over who was considered a good candidate for a cochlear implant and set new standards for the indication and selection of patients for this procedure.

People with severe to profound hearing loss who do not benefit from traditional amplification have increasingly turned to cochlear implantation in the last 30 years. A cochlear implant (CI) is a sensor device that is surgically inserted into the skull. It takes in sound waves, processes them through a series of filters, and then sends the resulting electrical impulses to specific electrodes stimulated along the cochlea's scale tympani.

Bypassing damaged hair cell transducers and directly stimulating residual auditory nerve components, implantation of electrodes in specific areas of the cochlea allows for the delivery of electrical impulses. The external equipment that provides encoded signals to the CI is a transmitter, signal processor, and microphone (Laurie S., Eisenberg, et al., 2006).

Aim of the study:

This research set out to document the cochlear implant program in Kuwait, how it was implemented, and the results achieved for the children who participated.

Subjects and methods:

On April 1, 2001, the Kuwaiti Cochlear Implant Program was launched. This study looked at children referred to the Sheikh Salem Al-Ali Centre for Audiology and Speech in Kuwait from various hospital departments and clinics, with a focus on neonatal, ENT, pediatrics, and genetics services. The children had to be at least 18 years old. Patients who had undergone cochlear implant surgery, regular follow-ups with device programming, and speech therapy sessions in Kuwait were included in the study, along with their gender and whether they were Kuwaitis or those from another country.

The government of Kuwait has financed the majority of patients who visited audiology clinics since the program's inception in 2001, while the Social Affairs department has provided funding for patients of various nationalities beginning in 2011.

At the initial appointment, the patient's family history was meticulously documented. Typically, parents were the ones who supplied the information. As per the program's protocol, patients had undergone comprehensive audio logical evaluation. Using a free field test with a loudspeaker, we measured the hearing threshold levels of infants and toddlers at 500, 1000, 2000, and 4000 Hz, depending on their age. The auditory pathway integrity up to the inferior colliculus was evaluated using an evoked potential test (EBR) that used both a click and a tone burst stimulus. Transient evoked optoacoustic emissions (TEOAE) were used to detect the mechanical function of the outer hair cells and to identify cases of auditory neuropathy. In order to diagnose or rule out issues with the middle ear, an immitancemetry test was performed. When it came time to evaluate their speech, most of the kids were already pre-lingual, but those who could were given a list of 25 monosyllable words to practise on.

Radiological studies, including computerized tomography (CT) scans and magnetic resonance imaging (MRI), were performed in all cases to detect or rule out congenital abnormalities of the auditory system and pathways. They were also referred to the genetic department for genetic study and genetic analysis. The pediatric developmental department of Sabah Hospital also administered assessments to this cohort.

Patients were chosen in accordance with the study's protocol, which stipulated that they had to be at least 18 years old, have a hearing level of at least profound SNH, be of randomly selected gender, and have no aids to their hearing. Patients who have undergone cochlear implant surgery, have a hearing loss of 65 dB or higher, and have speech discrimination of 30–40%, with some patients not benefiting at all or experiencing a plateau level before the aids stopped helping. An important criterion for surgery was a good overall medical condition, normal mentality, and average intelligence test results of < 80%.

One of the most crucial factors taken into account while choosing candidates for the procedure was the level of motivation shown by both the patients and their family. Members of the Kuwaiti cochlear implant team, including an otolaryngologist, a psychologist, a speech therapist, an audio-vestibular-medicine specialist, and a social worker, counselled patients and their families before deciding to proceed with surgery.

Children who did not meet the inclusion criteria for this study were those who were deemed to have severe abnormal behaviour, learning disabilities, or who were not receiving rehabilitation in Kuwait. Additionally, children who did not follow up to program the devices were also not included.

Age, gender, nationality, and implant-related age were among the demographic variables reported for every patient. After surgery, patients' postoperative hearing threshold levels, speech reception thresholds, speech discrimination, device types, strategies, and stimulation rates were recorded, among other clinical variables. After that, all of the data was imported into a computer system for further examination.

Statistical Analysis:

The researchers used IBM Corp's (Armonk, NY, USA) "Statistical Package for the Social Sciences, SPSS version 25.0" software to manage, Analyse, and display the data graphically. Categorical variables' descriptive statistics have been shown as numbers and percentages. To ensure that the quantitative or continuous variable implant age follows a normal distribution, the Kolmogorov-Smirnov test was used. The results are displayed as the mean + standard deviation (SD) and range. We used chi-square or Fisher's exact test to look for significant differences or associations between the categorical variables. For the purpose of comparing the mean implant ages among groups, either Student's t-test or Analysis of Variance (ANOVA) were employed. When the two-tailed probability value 'p' was less than 0.05, it was deemed to have statistical significance.

Results:

- **Demographics:**

The overall mean implant age of 177 children, between 1 to 12 years of age, was found to be 3.86 (± 2.25 SD) years (Table 1). Of the total 177 children, 93 (52.5%) were males, and 84 (47.5%) females. Nationality-wise, 126(71.2%) children were Kuwaitis, and remaining 51(28.8%) non-Kuwaitis. Maximum 123 (69.5%) children were <5 years of age. No significant differences were found between gender, and nationality status with respect to implant age (p>0.05). (table 1).

- **Clinical Features:**

The various clinical features and their distribution, associated with cochlear implants in children, have been presented in Table 2. Almost 95% of cases had severe to profound HL, while predominantly it was on right side 112(63.3%). Almost 50% implant device used was nucleus type (C124R-CA). The distribution of post-operative HL on both sides was almost similar, around 90% with in 45dB. Simulation rate among 73.7% children was ≤ 900, and only 6% were >1200. Almost 55.3% had speech reception threshold (SRT) within 10-30dB, while speech discrimination (SD) was noticed >75% among 58.3% children.

- **Loss of hearing and Implant devices:**

The side of implantation was mostly on the right side in 112 (63.3%) children, and on the left. in 61 (34.4%) Table 3. Bilateral cochlear implantation was found in 4 (2.3%) children, one with implant age of 1 year, 2 at age of 2 years, and 1 was 3 years old. Post- operative hearing level was maximum (60.9%) on Rt. Side in the range of 31-45dB for implant age of 2 to < 7 years, while on the Lt. Side, maximum (62.5%) was found in (7- 12) years with same range hearing level. The post-operative hearing level on both, right and left sides, with respect to implant age was about 50% (31-45dB), 40% (10-30dB) and 10% (>45 dB). No significant difference was found (p=0.650).

- **Post-operative hearing level and speech reception threshold (SRT):**

Post-operative hearing level with respect to age has been shown in Table 4. In SRT, the maximum cases (55.1%) were those with (10-30dB), followed by 29.7% (31-45dB)., and minimum (4.4%) with > 45dB while 10.8% were SDT, which means that they were only detecting the sound without any discrimination.

- **Cochlear Device and Implant Age:**

Majority of 145 (81.9%) children, were implanted with nucleus type of device (C124R- CA=50.8%, C124R-ST=18.1%, C124-M & C122-M=13%) (Table 4). The other devices implanted were Advance bionic (6.8%), and MED-El (11.3%). Nucleus type (C124 R–CA) and (C124 R–ST) were the most commonly implanted Cochlear devices in the age group (1 to <5) years, while C124M was almost equally implanted in all the age groups (Table 4). Maximum implanted devices were Nucleus device C122 M, and Advance Bionic in children in the age group (2 to <5) years, while implant of MED-EL device was in the age group (2 to <7) years. The device implanted in children on both sides has been presented in Fig 1.

- **Speech Reception Threshold (SRT) and Speech Discrimination (SD):**

Maximum implant children with speech detection, SRT (10-30dB) and SRT (31-45dB), were in the age group (1 to <5) years, while SRT > 45 in the age group (1 to < 2) years. As regards Speech Discrimination, maximum children were benefitted with >75% SD in all age groups, especially in (1 to <5) years. The speech discrimination, and the device implanted in children, has been presented in (table 5 and Fig. 2).

- **Stimulation rate and speech discrimination (SD):**

Maximum cases had the stimulation rate ≤ 900 (73.7%), followed by 901-1200 (20.3%) and >1200 (6.1%). As regards speech discrimination, maximum cases >90% (37.1%) were Post lingual (>0.90), 0.76-0.90 (13.6%), <0.60 (11.4%), 0.61-0.75 (9.1%), and those who were having severely distorted speech and others (7.6%), while pre-lingual (21.2%), (table 5).

- **Complications in cochlear implanted cases (immediate and late):**

There were some complications following the operation; immediate and late ones. Out of total patients, one was reclosed and the surgeon did not proceed with the operation due to abnormal facial nerve course. One of the patients showed difficulty in reaching the scale tympani, hence, the electrodes were implanted in the scale vestibule. One child developed infection, immediate secretary otitis media, followed rapidly by mastoiditis post- operatively, and accordingly the patient had been explanted, and re-implanted again two months later. Two, implanted cases in Kuwait, had device failure complication; in one Nucleus type, the failure occurred 10 years after the first implantation, while the other, with MED-EL device, had immediate

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postoperative complication, however, both were re- implanted later and they are doing well.

Discussion:

- Cochlear implant operation showed a dramatic change in the life of the children with hearing loss, in our study, especially those with severe to profound hearing loss, and with no experience of sound. An early care in such cases, could have resulted almost in normal hearing, normal speech development, as well as normal process of education, which in turn resulted in their catching up with normal peer groups.
- The majority of children showed good results regarding hearing threshold levels, and speech development post cochlear implant operation, good programming of the devices and proper speech rehabilitation, as well as good family share in our program. A number of patients showed their hearing level ranging between (10-30dB), 2 cases showed levels between (60-70dB), 8 cases (3.5%) between (40-55dB), and the rest, a majority between (30-40dB).
- Out of 177 patients, 104 total children (58.8%) developed speech, and became post- lingual after receiving intensive speech therapy in our center, with the share of the families and the range of speech discrimination score from < 60% up to >90%. 28 children (10.7%) remained prelingual, if, they did not develop speech unfortunately and the main reason was that they never showed up after switching on their device and did not care for receiving speech therapy properly, although, through counselling them they had been told how much it is important after the operation and switching on the device to bring the hearing level to the near normal level. and another ten showed poor score, again the problem was the attendance of speech therapy sessions. This proves the importance of the criteria of having both children, and their families motivated for the operation, as well as the importance of attending the speech therapy sessions regularly post operation, and switching on their devices. In addition, counseling of both the patients and their families was an important issue to consider before and after implantation, to have the best results of operation, adding to the criteria the motivation of both the patient as well as the family. As regard the different types of devices we did not find any difference in the hearing levels or speech score results between different types of the devices or the stimulation rates.
- Based on the results and the complications seen, it proved that cochlear implant operation program in Kuwait is a successful one, and resulted in a dramatic improvement in the quality of life of children, catching up with their peer group as well as their academic and school performance.
- Upgrading our protocols and criteria of choosing the candidates is changing over years to match all over the worlds. We expanded the criteria to involve the moderately-severe to profound SNHL, deeply sloping SNHL, better aided hearing level with poor benefit, border line cases to improve their communications and academic performance. Bilateral cochlear implantation is the rule for the children either simultaneous or sequential, which had been started since 2013. All ages being chosen in our program, including adults and elderly, who are fit medically for cochlear implant operations.

Conclusion:

- Cochlear implant devices, operation and the rapidly progressing technologies of the implant devices came to the world and made a dramatic change in the life in patients who are having severe to profound hearing losses and did not show any benefit from hearing aids. As regard children who are undergoing the operation at a proper time (age of implantation) are catching up with their peer group, they developed good speech because they had regular follow up with regular programming and fine tuning of the devices, received a proper speech rehabilitation programs. Therefore, they showed normal, good outcome and had normal academic performance as well.
- Thus, we concluded that, cochlear implant program is a successful program all over the world including our country Kuwait. The study findings confirm that the cochlear implant program in Kuwait is a successful program and is on similar lines as in many other countries.

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Table 1: Demographic characteristics of children with Cochlear Implantation in Kuwait:

Imp. Age (years)	Mean age ± SD	Gender		Nationality Status		Total
		Male	*Female*	*Kuwaiti*	*Non-Kuwaiti*	*No (%)*
1 to <2	1.84 ± 0.35	32 (34.4)	25 (29.8)	39 (30.9)	18 (35.3)	57 (32.2)
2 to <5	3.35 ± 0.55	34 (36.6)	32 (38.1)	50 (39.7)	16 (31.4)	66 (37.3)
5 to <7	5.42 ± 0.50	16 (17.2)	17 (20.2)	21 (16.7)	12 (23.5)	33 (18.6)
7 to 12	8.56 ± 1.75	11 (11.8)	10 (11.9)	16 (12.7)	5 (9.8)	21 (11.9)
All children	**3.86 ± 2.25**	**93 (100.0)**	**84 (100.0)**	**126 (100.0)**	**51 (100.0)**	**177 (100.0)**
p-value	**<0.001**	**0.909**		**0.560**		

Table 2: Clinical features associated with Cochlear Implant among children:

Clinical Features	No	%
Side of Hearing Loss(HL)		
Right	112	63.3
Left	61	34.5
Bilateral	4	2.3
Implant Device		
Nucleus type:		
C124R(CA)	90	50.8
C124R(ST)	32	18.1
C124 M	17	9.6
C122 M	6	3.4
Advance Bionic	12	6.8
Med-El	20	11.3
Postoperative HL on Rt		
10-30 dB	41	39.8
31-45 dB	53	51.5
> 45 dB	9	8.7
Postoperative HL on Lt		
10-30 dB	23	38.3
31-45 dB	29	48.3
> 45 dB	8	13.3
Stimulation Rate		
≤ 900	98	73.7
901-1200	27	20.3
>1200	8	6.0
Speech Reception Threshold (SRT) Groups		
SDT	17	10.7
10-30	88	55.3
31-45	47	29.6
> 45	7	4.4
Speech Discrimination (SD) Groups		
Pre-lingual	28	21.2
< 0.60	15	11.4
0.61-0.75	12	9.1
0.76-0.90	18	13.6
>0.90/Post lingual	49	37.1
Distorted or Others	10	7.6

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Table 3: **Percent post-operative hearing loss according to implant age and side of implant:**

Implant Age	N	Rt. Side			N	Lt. side		
		10-30dB	***31-45dB***	***> 45dB***		***10-30dB***	***31-45dB***	***> 45dB***
Implant age	N	Rt side			N	Lt side		
		10-30dB	31-45dB	>45dB		10-30dB	31-45dB	>45dB
1 to <2	37	47.2	44.4	8.3	17	47.1	52.9	-
2 to <5	47	31.0	61.9	7.1	19	42.1	36.8	21.1
5 to <7	17	35.7	57.1	7.1	16	25.0	50.0	25.0
7 to 12	11	54.5	27.3	18.2	8	37.5	62.5	-
Total	**112**	**44(39.8)**	**58(51.5)**	**10(8.7)**	**61**	**23(38.3)**	**30(48.3)**	**8(13.3)**

Table 4: **Implant related factors according to age at implant:**

	Implant age-groups (years)				
Implant related Factors	***1 to <2 (n=57)***	***2 to <5 (n=66)***	***5 to <7 (n=33)***	***7 to 12 (n=21)***	***1 to 12 (n=177)***
Cochlear Device					
Nucleus type					
C 124 R (CA)	35	34	12	9	90 (50.8)
C 124 R (ST)	9	10	7	6	32 (18.1)
C124 M	4	5	4	4	17 (9.6)
C 122 M	1	4	-	1	6 (3.4)
Advance Bionic	3	7	2	-	12 (6.8)
MED-EL	5	7	7	1	20 (11.3)
Speech Reception Threshold					
Speech detection	4	7	4	2	17 (10.7)
10-30 dB	30	37	14	7	88 (55.3)
31-45 dB	15	15	9	8	47 (29.6)
> 45 dB	4	-	2	1	7 (4.4)
Speech Discrimination					
Pre-lingual	7	10	7	4	28 (21.2)
< 0.60	4	6	2	3	15 (11.4)
0.61-0.75	5	2	3	2	12 (9.1)
> 0.75	23	27	10	7	67 (50.7)
Others/distorted	4	3	1	2	10 (7.6)

Table 5: **Cochlear Implant cases according to Implant Device and Speech Reception Threshold and Stimulation Rate:**

	Speech Reception Threshold				Stimulation Rate		
Implant Device	**SDT**	**10-30dB**	**31-45dB**	**>45dB**	**<=900**	**901-1200**	**>1200**
Nucleus type							
C 124 R (CA)	4 (4.8)	54 (65.1)	21 (25.3)	4 (4.8)	56 (66.7)	23 (27.4)	5 (6.0)
C124 R (ST)	5 (17.2)	12 (41.4)	10 (34.5)	2 (6.9)	26 (86.7)	4 (13.3)	0
C124 M	3 (18.8)	7 (43.8)	6 (37.5)	0	12 (100.0)	0	0
C122 M	0	2 (100.0)	0	0	4 (100.0)	0	0
Advance Bionic	3 (25.0)	4 (33.3)	5 (41.7)	0	0	0	3 (100.0)
Med-EL	2 (12.5)	8 (50.0)	5 (31.3)	1(6.3)	-	-	-
Total	**17 (10.8)**	**87 (55.1)**	**47 (29.7)**	**7 (4.4)**	**98 (73.7)**	**27 (20.3)**	**8 (6.1)**

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Table 6: **Cochlear Implant cases according to Implant Device and Speech Reception Threshold:**

	Speech Discrimination Level					
Implant Device	**Pre-lingual**	**<0.60**	**0.61- <0.75**	**> 0.75**	**Others/ Distorted**	**Total**
Nucleus type						
C 124 R (CA)	7 (10.4)	10 (16.5)	5 (7.5)	37 (55.2)	7 (10.4)	67
C124 R (ST)	8 (28.6)	2(7.1)	6 (21.4)	10 (35.7)	2 (7.1)	28
C124 M	2 (15.4)	1 (7.7)	1 (7.7)	9 (69.2)	0	13
C122 M	0	1 (33.3)	0	2 (66.7)	0	3
Advance Bionic	7(58.3)	0	0	4 (33.4)	1 (8.3)	12
Med-EL	4 (44.4)	0	0	5 (55.6)	0	9
Total	**28 (21.2)**	**15 (11.4)**	**12 (9.1)**	**67 (50.7)**	**10 (7.6)**	**132**

Fig 1:

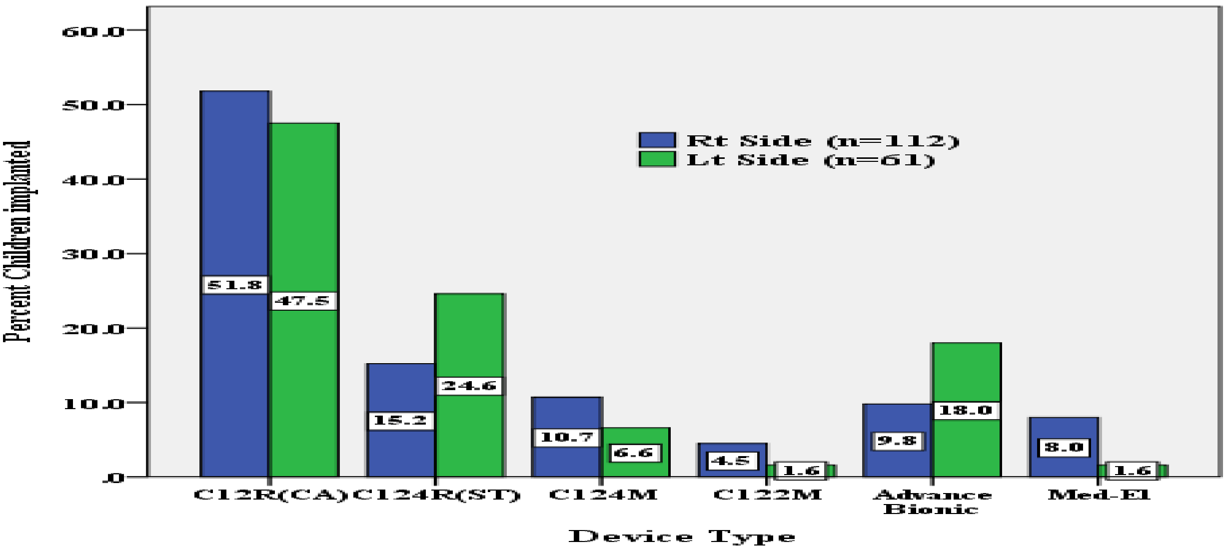
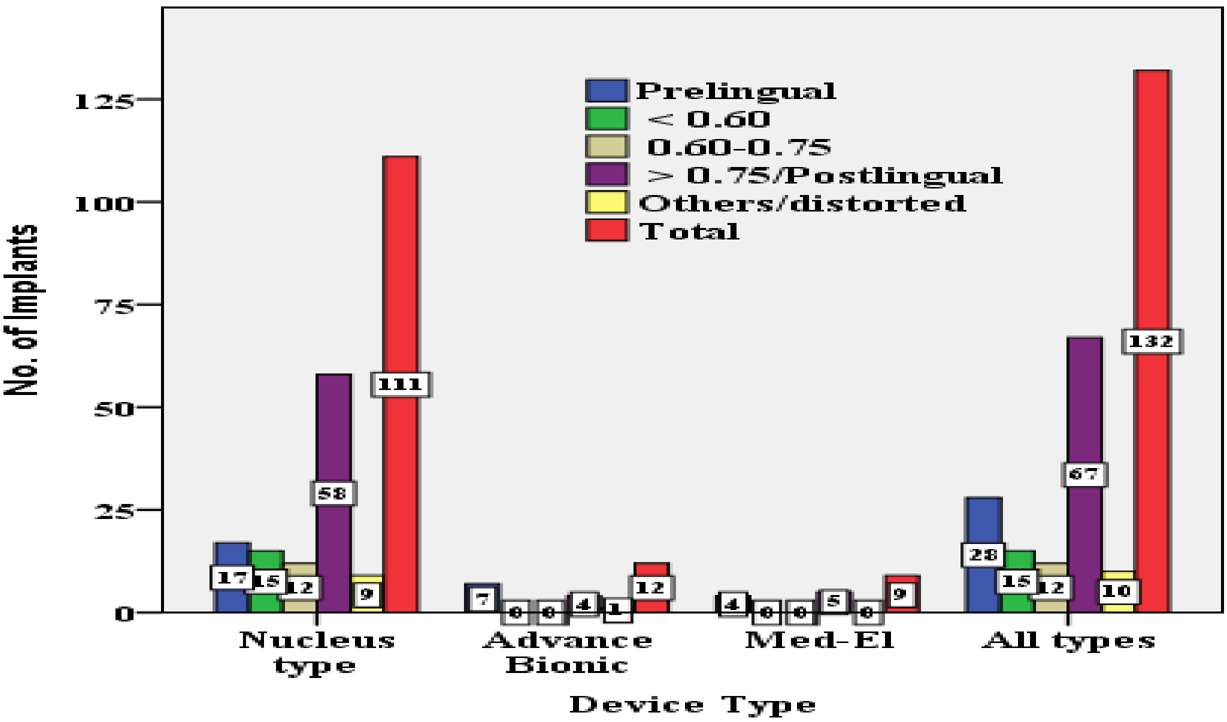

Percent Children implanted
60.0
50.0
40.0
30.0
20.0
10.0
.0
Rt Side (n=112)
Lt Side (n=61)
51.8
47.5
15.2
24.6
10.7
6.6
4.5
1.6
9.8
18.0
8.0
1.6
C12R(CA)
C124R(ST)
C124M
C122M
Advance Bionic
Med-El
Device Type

Fig. 2:


No. of Implants
125
100
75
50
25
0
Prelingual
< 0.60
0.60-0.75
> 0.75/Postlingual
Others/distorted
Total
17
15
12
58
9
111
7
0
0
4
1
12
4
0
0
5
0
9
28
15
12
67
10
132
Nucleus type
Advance Bionic
Med-El
All types
Device Type