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"What should be expected success with cochlear implant in school-aged children who have early and late intervention?"

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ABSTARCT

Aim: To evaluate sub-components of language skills in children with cochlear implant and to emphasize the importance of early diagnosis and intervention.

Methods: Cochlear implanted children aged 48 to 107 months (n = 70) were included in this study. The children were divided into two groups based on their diagnosis-intervention timing: those who used hearing aids and were enrolled in auditory rehabilitation before 6 months, as well as those who had cochlear implants before 24 months, were in the early group, while the others were in the late group. The "Test of Language Development Primary Fourth Edition (TOLD-P: 4)" and the "Phoneme Recognition Test (PRT)" were used to assess language sub-component skills.

Results: The early group's language performance was considerably higher than the late group's. The statistically positive correlations between PRT and Word Identification, Phonemic Analysis, Articulation tests were found.

Conclusion: This study demonstrates the importance of early diagnosis-intervention for hearing loss and that the main success of cochlear implant should be in all components of language.

Keywords: children, cochlear implant, early intervention, language

ÖZ

Erken ve geç müdahale alan okul çağı koklear implantlı çocuklarda beklenen başarı ne olmalıdır? "

Amaç: Koklear implantlı çocuklarda dil becerilerinin alt bileşenlerini değerlendirmek ve erken tanı ve müdahalenin önemini vurgulamak bu çalışmanın temel amacıdır.

Materyal ve metot: Bu çalışmaya yaşları 48 ile 107 ay (n = 70) arasında olan koklear implantlı çocuklar dahil edilmiştir. Çocuklar tanı-müdahale zamanlamalarına göre iki gruba ayrılmıştır. Erken grupta; 6 aydan önce işitme cihazı kullananlar, işitsel rehabilitasyona başlayanlar ve 24 aydan önce koklear implantasyon geçirenler yer almaktadır. Geç grupta ise 6 aydan sonra işitme cihazı ve rehabilitasyon başlangıç yaşı olup, 24 aydan sonra koklear implantasyon geçiren çocuklar yer almaktadır. Dilin sentaks ve semantik alt bileşenlerine yönelik becerilerini değerlendirmek için "Türkçe Okul Çağı Dil Gelişimi Testi" ve fonolojik işlemleme becerilerinin değerlendirilmesi için "Konuşma Seslerini Tanıma Testi" kullanılmıştır. Bulgular SPSS programı ile analiz edilmiştir ve tip 1 hata düzeyi 0,05 olarak belirlenmiştir.

Bulgular: Erken gruptaki çocuklar dile ilişkin tüm alt testlerde geç gruptaki çocuklara göre daha iyi performans göstermiştir. Ayrıca; konuşma seslerini tanıma becerileri ile kelime tanımlama, fonemik analiz ve artikülasyon becerileri arasında istatistiksel olarak pozitif korelasyonlar bulunmuştur.

Sonuç: Bu çalışma, işitme kaybı için erken tanı-müdahalenin önemini ve koklear implantın asıl başarısının dilin tüm bileşenlerinde olması gerektiğini göstermektedir.

Anahtar kelimeler: çocuklar, koklear implant, erken müdahale, dil

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INTRODUCTION

Auditory perception is the response of the auditory pathways to auditory stimuli by relating sound and object/event (Nerbonne & Show, 2002). Speech perception, on the other hand, requires consideration of the different input, which is more sophisticated and linguistic than other sound sources. The communication environment, as well as all language components (phonology, morphology, syntax and semantics, pragmatics), are concerned with speech perception (Pickles, 2013).

Cochlear implantation and language skills have been interesting issues for researchers from past to present. According to these researches, cochlear implantation significantly improved auditory perception, receptive and expressive language skills (Lu & Qin, 2018; Scarabello et al., 2020). Apart from comorbidities or social limitations, a review study revealed that the cochlear implant (CI) improves hearing and speaking ability (Sharma, Cushing, Papsin, & Gordon, 2020). The expected success of

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the CI is to be mainly the acquisition of spoken language and individuals can communicate in this way; however the real success should be that children successfully use language in all its components. Because the language is more than just a spoken language, it also has a complicated structure that includes semantics, syntax, and pragmatics (Lahey & Bloom, 1988; Smiley & Goldstein, 1998). Therefore, the children with early cochlear implanted may be able to demonstrate poor performance in other components of the language even if they are good at spoken language (Cupples, Ching, Crowe, Day, & Seeto, 2014; Wass et al., 2019). Undoubtedly, the cochlear implanted child should be able to discriminate the linguistic information in the acoustic speech signal with regards to lexical, semantic, phonetic and sociolinguistic cues. Thus, acquisition of a spoken language in child with CI is insufficient for speech and language development, academic achievement and communication skills, and so additional support needs may continue.

Some studies emphasized that lexical skills and auditory-verbal memory had a strong relationship with morphosyntactic development, also grammatical knowledge was very important (Barajas, González-Cuenca, & Carrero, 2016; de Hoog et al., 2016; Yoshida, Takahashi, Kanda, Kitaoka, & Hara, 2017). The language-based skills such as word recognition, categorization of words and the object-function relationship became more difficult for children with hearing loss (Ching, Cupples, & Marnane, 2019; Delage & Tuller, 2007; McCreery, Walker, Spratford, Lewis, & Brennan, 2019; Tomblin, Oleson, Ambrose, Walker, & Moeller, 2014; von Koss Torkildsen, Hitchins, Myhrum, & Wie, 2019). Although there are studies evaluating other high-level skills such as reasoning, pragmatics and syntax in addition to language skills used in daily life in children with cochlear implants, the current study contributes to the literature in terms of evaluation tools.

One of the most important issue on cochlear implant is an improvement in language skills with early diagnosis and intervention (Shojaei et al., 2016; Yoshinaga-Itano, Sedey, Wiggin, & Mason, 2018). The temporal processing skills of cochlear implanted children even with early diagnosis and intervention are worse than normal hearing peers (Tuz, Aslan, Böke, & Yücel, 2020). A study showed that children were diagnosed more than three months later than the ideal time and intervention began later (Percy-Smith et al., 2018). Therefore, many studies have been stated that early diagnosis and intervention through ideal rehabilitation is vital (Akçakaya, Doğan, Gürkan, Koçak, & Yücel, 2019; Ching et al., 2017). On the other hand, there is limited agreement among experts on the precise meaning of early intervention (Mitchell et al., 2019; Wenrich, Davidson, & Uchanski, 2019). Although the diagnosis of hearing loss is much earlier with newborn screening programs, delays in amplification and rehabilitation support have resulted in late intervention. Therefore, children's language development and other related skills can be still behind the normal hearing peers. This study would be useful in terms of contributing to the literature, since the children used hearing aids before they were 6 months old and had cochlear implants before the age of 2 years. The present study differs from other similar studies in terms of age limit for early diagnosis, number of participants and evaluation methods. Thus, this study aims to guide the experts studying about hearing loss in terms of rehabilitation.

To the best knowledge of authors, there is little research focusing on the language sub-components skills of cochlear implanted children. Especially, although the limited number of other studies evaluating the sub-components of language with the test of language development (TOLD), the current study was aimed to contribute to the literature by adding different subtests. Many studies, including the current one, aim to provide better rehabilitation support to children with cochlear implants and thus provide more holistic language acquisition as a result. The present study primarily aimed to present a new perspective in terms of including distinctive evaluations of the sub-components of language. The second goal of this study was to demonstrate that the expected success of a cochlear implant (CI) in these children involves not only acquisition of daily spoken language but also proficiency in semantics-syntax components of language. Identifying the weaknesses of all components of the language and planning the intervention in this way can provide much better results in the future about communication, social skills and academic achievement. Thanks to the findings, the importance of the development of sub-skills of the language such as phonology, morphology and syntax and early diagnosis-intervention would be revealed and this would provide improvements in rehabilitation programs in children with CI. The final purpose of this study was to shed light on the development and clinical follow-up in language-based abilities for experts.

MATERIAL AND METHODS

This study was conducted on Audiology Department of Faculty of Health Sciences at the University. This study was complying with the principles of Declaration of Helsinki, and The University Ethical Committee for Non– Interventional Clinical Research of the University approved this study with 16969557–819, GO 17/808 decision number and code. All the children and their parents agreed to participate in the study and signed an informed consent.

The study included children who had a cochlear implant in at least one ear for at least a year and spoke monolingual Turkish. The children with inner ear or auditory nerve defects, who have been multi-handicapped, and who are unable to cooperate with the tests were excluded. The children in the early group received hearing aids before the age of six months, were enrolled in an auditory rehabilitation program before the age of six months, and got their first CI before the age of twenty-four months (n=34, 15 of them female). The late group included participants

Table 1. The descriptive criteria of scores on TOLD-P: 4 sub-tests.

Standard Score	**1-3**	**4-5**	**6-7**	**8-12**	**13-14**	**15-16**	**17-20**
Descriptive categories	Very poor	Poor	Below-average	Average	Above average	Excellent	Very Excellent
Index Score	<70	70-79	80-89	90-110	111-120	121-130	>130

who received their first hearing aid after 6 months and acquired cochlear implants after 24 months (n=36, 18 of them female). To eliminate crossover, children who received no hearing aids before the age of 6 months but were implanted before the age of 2 years were omitted. About companies, 40 out of 70 children had Cochlear, 17 of them Medel and 13 of them Advanced Bionics. The children were randomly selected according to the order of the acceptance to the clinic, and no distinction was made between the CI companies.

The demographic, audiological, and educational data about the children was collected from families and recorded by the researcher via a Participant Information Form. This form includes data on children's residual hearing, ear side, risk factors, audiological history, etc. Hearing thresholds of at least 80–90 dB HL in at least two of the frequencies of 125, 250, and 500 Hz in 27 individuals who were thought to have residual hearing were accepted in accordance with the pure tone hearing thresholds and auditory brainstem response findings prior to cochlear implant surgery. A total of 81 children with CIs were initially evaluated, but 11 of them were excluded because of the cooperation problems. The children had free field thresholds of approximately 20–30 dB HL between 250 and 6000 Hz on average with their cochlear implants. The ear that had the first cochlear implant surgery was chosen since it was an experienced ear. The Turkish version of the "Test of Language Development Primary Fourth Edition (TOLD-P: 4)" test was used to evaluate the subcomponents of language (semantics and syntax skills) and total spoken language performance of children between the ages of 4 and 8 years and 11 months. The Phoneme Recognition Test (PRT) was applied to evaluate the phoneme recognition skills at the level of central auditory processing.

The validity and reliability of the Turkish version of TOLD-P: 4 tests were completed, and the test achieved minimum psychometric evaluation standards (Topbaş & Güven, 2017). The TOLD-P: 4 are composed of six core tests (picture vocabulary, relational vocabulary, vocabulary description, sentence comprehension, and sentence repetition and morpheme completion) and three complementary tests (word differentiation, phonologic analysis, word production). In addition to these, some basic skills are combined with one another or complementary skills, and some composite skills such as listening, speech, grammar, and semantic are achieved. When all of the six sub-test scores are combined, spoken language score is obtained. At the end of the evaluation, the final scores obtained and the chronological age calculated are taken to the relevant table and the scale scores, percentage values, index scores, descriptive categories corresponding to each subtest are determined. The scaled score is the score obtained after the continuous normalization study according to the final scores, and thus there is no base effect in any subtests (Newcomer & Hammill, 1988; Topbaş & Güven, 2017) (Table 1).

The Phoneme Recognition Test (PRT), the standardization of which was studied by Küçükünal et al. and recommended to be used for 6 years and older, was used to investigate how phonemes are perceptually processed at the level of the central auditory system in children with CI (Katz, Chasin, English, Hood, & Tillery, 1978; Katz & Tillery, 2004; Küçükünal, 2012). There are 58 phonemes in the PRT list and the score is determined by numbers of correct recognitions. The PRT audio file was presented via CI fitting software to implanted ear side. To our knowledge, this is one of the first studies by means of direct stimulation to CIs in terms of presenting audio file, so there is no need to use a loudspeaker, which helped us avoid from background noise (Di Nardo et al., 2015; Kurien et al., 2019; Schmitt, Winkler, Boretzki, & Holube, 2016). The experienced ear which refers to the ear undergoing first cochlear implant surgery was tested in bilateral CI users. Table 2 provides the categories and scores about the number of accurately recognized phonemes.

Table 2. PRT Standard Scores and Disorder Criteria.

The groups by standard deviation	**Score**	**Category**	**Number of Accurately Recognized Phoneme**
+1 SD	49	Normal	49-58
Average	44	Mild	44-48
-1 SD	39	Moderate	39-43
-2 SD	34	High	29-38
-3 SD	29	Very High	0-28

SPSS version 22 for Windows 7 was used for the statistical analyses and a p value <0.05 was considered statistically significant. The variables were investigated using visual (histogram and probability plots) and analytical methods (Kolmogorov-Smirnov/ Shapiro Wilk's test) to determine whether or not they were normally distributed. Descriptive analyses were presented using mean and standard deviation for normally distributed variables. Statistical significance was analyzed by using an Independent Samples t-test for TOLD-P: 4 sub-test scores and a Mann Whitney U test was used to compare phoneme recognition test scores between the groups. The correlation coefficients and their significance were calculated using a Pearson Correlation test to define the relationship between scores of TOLD-P: 4 sub-test and PRT.

RESULTS

The mean age of early diagnosed-intervened groups was 75.71±18.11 months (ranged 48–106 months, 15 of 34 children were female) and; in the late group, half of children were female, and the mean age of group was 76.16±18.25 months (ranged 48–104 months), also there were no significant differences between the groups. While the age of cochlear implantation was 18.2±5.0 months in the early diagnosed-intervened group, it was 38.0±6.4 months in the late group. The duration of cochlear implant use was 57.5±12.8 months in the early diagnosed-intervened group, while it was 37.8±10.6 months in the late group (Table 3).

Table 3. Descriptive Statistics of Children in Early and Late Groups.

Groups/ Variables	Early diagnosed-intervened (n = 34)	Late diagnosed-intervened (n = 36)	*p* value
Female – Male (n, %)	15, 44.11% – 19, 55,89%	18, 50% – 18, 50%	0.89
Age (in months as mean ± SD)	75.71 ± 18.11	76.16 ± 18.25	0.75
Age of hearing loss diagnosis (in months as mean ± SD)	4.2 ± 1.8	16.15 ± 7.2	0.001*
Age of hearing aid usage (in months as mean ± SD)	5.0 ± 0.9	18.10 ± 8.5	0.001*
Onset of auditory rehabilitation (in months as mean ± SD)	5.1 ± 0.4	22.20 ± 10.06	0.001*
Age of cochlear implantation (in months as mean ± SD)	18.2 ± 5.0	38.0 ± 6.4	0.001*
Duration of cochlear implant (in months as mean ± SD)	57.5 ± 12.8	37.8 ± 10.6	0.001*

*$p < 0.05$ was considered statistically significant.

According to TOLD-P: 4 sub-test scores the children in early group had 16% score and the late group had 4.78% score in picture vocabulary test. For the relational vocabulary test, 26.18% and 6.53% percentages were obtained in the early and late groups, respectively. For the vocabulary description test, the results were 31.21% and 9.89%, for the sentence comprehension test, 18.53% and 2.89%, for the sentence repetition test, 38.29% and 10.11%, and finally, 19.85% and 3.61% for the morpheme completion test in the early and late groups, respectively. There were significant differences in all of the sub-tests between the groups (Table 4).

Results of PRT on 37 children revealed that 32.4% of them had mild impairment, 27% had moderate impairment, and 27% had severe impairment. It was found that 13.6% of participants performed normally in identifying speech sounds. According to the Pearson correlation coefficient, there are strong relationships between PRT and word discrimination, PRT and word production test (r=0.596 and p=0.000, r=0.658 and p=0.000 respectively). A correlation was found between PRT and phonemic analysis test, but it was no statistically significant (r=0.299, p=0.082).

Table 4. The Values of Sub-Tests According to Early and Late Diagnosis-Intervention.

Early and Late Diagnosis-Intervention / scores		n	Average score (%)	Standard deviation	p value
picture vocabulary	early	34	16.00	10.660	< 0.001*
	late	36	4.78	4.127	
relational vocabulary	early	34	26.18	17.107	< 0.001*
	late	36	6.53	4.266	
vocabulary description	early	34	31.21	22.710	< 0.001*
	late	36	9.89	8.628	
sentence comprehension	early	34	18.53	19.158	< 0.001*
	late	36	2.89	2.594	
sentence repetition	early	34	38.29	15.430	< 0.001*
	late	36	10.11	7.058	
morpheme completion	early	34	19.85	19.788	< 0.001*
	late	36	3.61	2.370	

*p < 0.05 was considered statistically significant.

When the index values of the composite skills between the groups were examined, a statistically significant difference was found in the scores of Listening, Organizing, Speaking, Grammar, Semantic Knowledge, and Oral Language Index (mean values are shown in Table 5, p<0.001).

Table 5. The Index Scores Obtained in Composite Tests According to Early and Late Diagnosis-intervention.

Early and Late Diagnosis-intervention / index scores		n	Average index scores	Standard deviation	p value
Listening	early	34	80,15	6,091	<0,001*
	late	36	64,25	7,901	
Organization	early	34	90,74	6,943	<0,001*
	late	36	72,25	6,893	
Speech	early	34	85,71	11,129	<0,001*
	late	36	69,64	6,749	
Grammar	early	34	87,15	8,610	<0,001*
	late	36	70,14	6,388	
Semantics	early	34	84,91	7,229	<0,001*
	late	36	67,19	6,177	
Spoken Language	early	34	86,91	5,775	<0,001*
	late	36	72,00	6,370	

*p <0.05 was considered statistically significant.

The descriptive terms explained in Table 1 were analyzed according to the general score of oral language skills, which was created by considering all subtests of TOLDP-4. Accordingly, while two children in the early diagnosis-intervention group were in the "very poor" category, eighteen children in the late diagnosis-intervention group were in this category. Similarly, 11 children from the early group were included in the "average" category in oral language skills, while none of the children from the late group reached the "average" level (Fig. 1). The word discrimination and phonemic analysis tests could not be performed in some children due to cooperation difficulties. According to this, the mean of word discrimination scores were

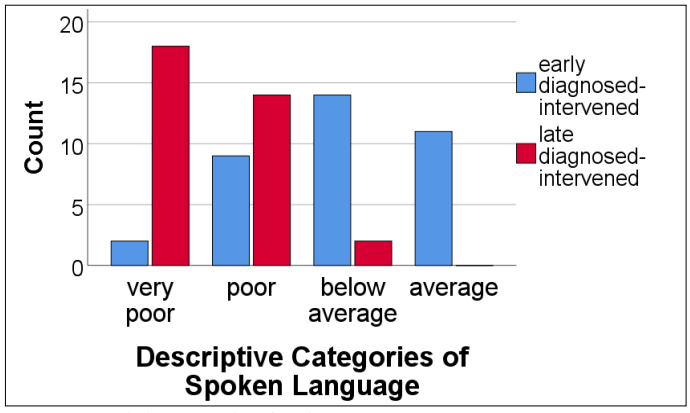

Figure 1. Descriptive Categories of Spoken Language Score

18.91±5.32 in 55 children, 14.6±5.99 points in phonologic analysis test which could be performed in 47 children, and 18.07±4.40 points in word production test in 70 children. When the scores obtained from the complementary tests, the scores were compared with a Mann Whitney U test, and a statistically significant difference was found between the early and late groups (For word discrimination test p=0.035, for phonemic analysis test p=0.027, for word production test p=0.048). Also, the scores obtained from these three complementary tests were found to be below the standardized normal scores.

DISCUSSION

This study originated from observations in our clinical assessments and experiences: 1) that children who have been implanted with CIs vary in terms of their language skills and may have poor phonological skills; and 2) very early access to speech sounds provided by the early cochlear implantation enables children to develop better language and phoneme recognition in pre/early school years. Although the total of the spoken language scores in the current study were higher than a particular cut off value, children with cochlear implants scored poorly when sub-skills were tested separately. For example, the children who had the descriptive term 'average' in spoken language were able to show poor performance in sentence comprehension and word description tests. This is probably due to the lack of emphasis on the follow-up and rehabilitation of high-level language skills after the acquisition of spoken language, which is sufficient to meet daily needs. Similarly, numerous researches have been conducted to investigate the effects of language-based skills on academic accomplishment and communication skills in the general profile (Nittrouer, Muir, Tietgens, Moberly, & Lowenstein, 2018; Zhang et al., 2018). The current findings are consistent with the results of earlier research that indicate children with CI had lower scores on the language component skills such as morphosyntactic, semantic and phonological skills than age-normalized scores (Golestani, Jalilevand, & Kamali, 2018; Pooresmaeil, Mohamadi, Ghorbani, & Kamali, 2019). Although the speech perception of children with CI is developed, it appears that a CI cannot completely reflect the physiological characteristics of normal hearing human ear (Niparko, Kirk, Robbins, Mellon, & Rucci, 2009). As in our present study, children with CI may perform poorly in skills for subcomponents of language, even if they are competent in using overall spoken language to receive the message in general. This is evident in reading skills, for example, because it is dependent on a variety of skills such as decoding, understanding spoken language, and receptive language performance. From this point of view, children with CI often performed badly in skills such as word decoding, vocabulary, and speech comprehension when compared to their normal hearing classmates (Martins, Queiroga, Rosal, & Cordeiro, 2018; Wass et al., 2019). The people with mild to severe hearing loss have been demonstrated clinically significant language impairments, which have detrimental consequences on phonological processing, receptive and expressive vocabulary and grammar, and communication skills (Halliday, Tuomainen, & Rosen, 2017; Penke & Wimmer, 2018). In this context, the results of the current study more closely reflect the importance of being proficient in language components skills rather than only spoken daily language.

The phonological processing abilities are impaired as a result of the decrease in frequency resolution caused by hearing loss (Bedoin et al., 2018; Marshall et al., 2018). Since the PRT is a test for assessing the central processing ability of phonologic recognition, it was investigated whether there was a correlation with the TOLD-P: 4 sub-tests of word discrimination, phonemic analysis, and word production. Similar to our current study, one study also suggested that there was a significant relationship between TOLD-P: 3 language test and phonological awareness skills in children with cochlear implants (Soleymani, Mahmoodabadi, & Nouri, 2016). According to the current findings, phoneme recognition skills in children with cochlear implants may be lower in PRT tests due to a certain degree of impaired tonotopic organization and reduced spectral resolution in relation to the frequency range of speech sounds (DiNino & Arenberg, 2018; Grunwell, 1988; Molis & Leek, 2011). There are two approaches to phonological acquisition that help us explain this relationship between PRT and language skills; articulation competence and phonological competence (Grunwell, 1988). According to the study's findings, it is more crucial for language development to understand the placement of the phoneme inside the word and the meaning it gives to the word than the articulation of the target sound. As a result, while children with cochlear implants can articulate the phonemes, they struggle to understand their meanings at the core level and process them in words. These findings are consistent with previous research on the association between phoneme recognition and other skills (Holt, Lee, Dowell, & Vogel, 2018).

One of the most important points of the study was the definition of early intervention, which includes not only early diagnosis but also early usage of hearing aids, rehabilitation programs, and early cochlear implantation. Because of the infant's acquisition

of auditory abilities and exposure to meaningful auditory stimulation during the critical time is largely responsible for the development of normal language and speech (Buell & Coleman, 1979). Thus, the cells and their connections grow and develop through environmental stimuli. In this case, it can be said that; "The more diversity of experience and sensory input, the more cells and connections develop." In light of this idea, the vital importance of early diagnosis-intervention has been once again demonstrated in this study (Akçakaya et al., 2019; Ching et al., 2017; Colin, Ecalle, Truy, Lina-Granade, & Magnan, 2017; Mitchell et al., 2019; Novogrodsky, Meir, & Michael, 2018). Early detection and intervention in hearing loss, as is well known, is vital for the child to receive auditory stimuli during the critical time of development, as well as for the growth of neuronal connections in the structures of the auditory nerve system. This study also emphasizes the need of early intervention. There should be no delay before sensory-neural activation in the auditory system with the use of hearing aids can begin. Another issue that must be highlighted by early intervention is that no time is spent in deciding on a cochlear implant after a hearing aid follow-up. Moreover, unlike adults, children require more information about the auditory stimuli in order to process speech as a whole. Their knowledge and experience are limited in order to complete the auditory stimulus that is degraded or missing. Therefore, they need to receive all the auditory information clearly, hence it is very important that they are implanted at a young age (Thai-Van, Veuillet, Norena, Guiraud, & Collet, 2010). There have been studies that illustrate the significance of the age of cochlear implantation and exposure to speech perception by accessing linguistic clues (Colin et al., 2017; Novogrodsky et al., 2018; Park, Won, Horn, & Rubinstein, 2015). Similar to some studies, in our study, early diagnosed and intervened children were found to be more successful in the above mentioned skills TOLD-P: 4 subtests and composite performances (Gallego, Martín-Aragoneses, López-Higes, & Pisón, 2016; Geers & Hayes, 2011). The reasons why children with CI perform worse than age-normalized scores in the TOLD-P: 4 tests can be explained by the duration of deafness. Children may have suffered from irreversible auditory deprivation prior to receiving a CI. Another issue that must be addressed within the scope of early intervention is the inclusion of a successful auditory perception and rehabilitation program with early amplification as early as possible. Looking at Bleile's speech language development stages; (Clark & Clark, 1977) in order for hearing impaired children to get meaningful sensory input, earlier auditory perception and rehabilitative support should be provided (Monshizadeh et al., 2018; Roman, Rochette, Triglia, Schön, & Bigand, 2016). The current study highlighted the significance of early auditory rehabilitation strategies once again.

As previously stated, there are only a few researches on early auditory rehabilitation in the literature. To the best of our knowledge, this is the first study involving children who were included in the auditory rehabilitation program as early as 6 months of age and beyond. The children in our study frequently began the auditory rehabilitation program simultaneously with the use of hearing aids. More experience and comprehensive auditory perception therapies are required in the early stages to enhance the association between auditory skills and speech perception, as well as to create neural connections at the central auditory pathway.

According to the authors, this is the first study to analyze the age of diagnosis of hearing loss, age of hearing aid use and rehabilitation, and age of cochlear implantation all at the same time in early intervention. Because it is well recognized that auditory deprivation has a negative impact on language development, the importance of early intervention must be considered in children, and expectations from the CI should be shaped in this perspective.

CONCLUSION

The expected success of CI is generally acquiring and communicating of language in children, but the main success is that children successfully use language in all its components together with language acquisition. This study implies that early detection and treatment of hearing loss will entirely reveal the success of CI. The findings indicate that the greatest benefit from a cochlear implant should be achieved in all language components. In future research, the association between cognitive skills and performance in language components should be studied using a unique cognitive test tool for hearing impaired children. Acquisition of daily spoken language is insufficient for school-age cochlear implant users; it is essential to determine the strengths and weaknesses of language use in general and plan the rehabilitative program accordingly.

Ethics Committee Approval: Ethical approval for this study was obtained from Non-Interventional Clinical Research Ethics Committee (GO17/808)

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Informed Consent: Written informed consent was obtained from the participants.

Author Contributions: Concept – NYG; Design – NYG; Supervision - EY; Resources – NYG; Data Collection and/or processing – NYG; Analysis and/or interpretation – NYG; Literature Search – NYG; Writing Manuscript– NYG.

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