

## Original articles

# Percentage of correct consonants (PCC) in hearing impaired children: a longitudinal study

## *Porcentagem de consoantes corretas (PCC) em crianças com deficiência auditiva: estudo longitudinal*

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### ABSTRACT

**Purpose:** to obtain and compare the percentage of correct consonants rate in deaf children, cochlear implant or hearing aids users within a twelve-month interval. Additionally, the influence of aspects, such as, frequency in therapy, age at hearing impairment identification and hearing device, were also investigated in the percentage of correct consonants (PCC) index.

**Methods:** nineteen children with hearing impairment, hearing aids or cochlear implant and were in speech therapy participated in this research. The PCC index was calculated using three tests: naming, imitation and spontaneous speech, using the phonology tasks of ABFW's - Child Language Test. The procedures were applied and reapplied within a 12-month interval, thus, characterizing a longitudinal study.

**Results:** regarding the comparison of the PCC index, there was a statistically significant difference between the applications in all tests. An association of the average gain of percentage of correct consonants with frequency therapy was observed.

**Conclusion:** the PCC index obtained and compared in two occasions, revealed improvement in all tasks after 12 months of speech therapy using aural approach. Improvement in oral production and frequency in therapy directly influenced the improvement of oral language development of these children. Improvement in oral language development of these children was directly influenced by compliance to the therapy. The age at hearing loss identification and the daily use of the devices did not influence the PCC indexes.

**Keywords:** Hearing Loss; Auditory Perception; Child Development; Language Development; Cochlear Implants

### RESUMO

**Objetivo:** obter e comparar o índice de porcentagem de consoantes corretas em crianças deficientes auditivas, usuárias de Implante Coclear e/ou Prótese Auditiva num intervalo de doze meses. Além disso, buscou-se verificar a influência da frequência em terapia, da época da identificação da deficiência auditiva e do tempo de uso do dispositivo auditivo no índice de PCC.

**Métodos:** participaram desta pesquisa 19 crianças deficientes auditivas, usuárias de Prótese Auditiva e/ou Implante Coclear e que estavam em terapia fonoaudiológica. O índice de porcentagem de consoantes corretas foi calculado por meio de três provas: nomeação, imitação e fala espontânea utilizando as tarefas da prova de fonologia do ABFW - Teste de Linguagem Infantil. Os procedimentos foram aplicados, reaplicados e comparados, num intervalo de 12 meses, caracterizando um estudo longitudinal.

**Resultados:** em relação à comparação do índice de porcentagem de consoantes corretas, houve diferença estatisticamente significativa entre as aplicações em todas as provas. Observou-se associação do ganho médio de porcentagem de consoantes corretas apenas com a frequência em terapia.

**Conclusão:** a partir da obtenção e comparação em duas oportunidades do índice PCC em crianças deficientes auditivas, observou-se melhora em todas as tarefas após 12 meses de intervenção fonoaudiológica com a abordagem auricular. A melhora do desenvolvimento da linguagem oral destas crianças foi influenciada diretamente pela assiduidade em terapia. A época da identificação da deficiência auditiva e a tempo de uso do dispositivo não influenciaram os índices de PCC.

**Descritores:** Perda Auditiva; Percepção Auditiva; Desenvolvimento infantil; Desenvolvimento da Linguagem; Implantes Cocleares

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## INTRODUCTION

The diagnosis of hearing impairment has been occurring in an increasingly precocious manner due to the establishment of neonatal hearing screening programs. The child's language and speech skills are acquired primarily through listening<sup>1</sup>. The first months of life correspond to the most important period of sound stimulation, but hearing impaired children are deprived of this stimulation, which may impair the development of oral language if diagnosis and intervention do not occur in a timely manner<sup>2</sup>.

The development of the form and content of oral language occurs more slowly in hearing impaired children when compared to the development of the language of children with normal hearing<sup>3</sup>.

The change in speech production due to difficulty in speech perception is directly related to the degree of hearing impairment<sup>4</sup>.

The aural approach used in speech-language intervention in hearing impaired children is based on the use of residual hearing with the aid of the auditory device, be it the hearing aid and / or cochlear implant (CI), which allows the child to receive the greatest amount of the sounds of the idiom, which favors the development of oral language<sup>5</sup>.

The Percentage of Correct Consonant (PCC) index aims to quantify the severity and impact of communication disorders in the diagnostic classification system, in the execution of intervention plans more directed to the difficulties of the subject and in the therapeutic control. This measure is part of the classification system of the diagnosis of the phonological disorder, based on an increasing scale of severity<sup>6</sup>. The index of PCC values includes four severities: light, which corresponds to more than 85% of correct consonants; slightly moderate, ranging from 85% to 65%; moderately severe, ranging from 50 to 65%; and severe, indicated by values below 50% of correct consonants<sup>7</sup>.

PCC knowledge can assist the therapist in educational audiology to monitor therapeutic progress<sup>8</sup>.

In an earlier study, PCC rates in children with hearing impairment were lower when compared to audiologically normal children<sup>8</sup>.

A study of hearing impaired children, cochlear implant and/or hearing aid users showed that the intervention based on the stimulation of vocabulary is effective and its effectiveness was verified by comparing the percentages of correct consonants, in which an improvement of 14 and 15% was observed<sup>9</sup>.

Longitudinal studies have shown the effectiveness and efficiency of the application percentage of the correct consonant index for monitoring the therapeutic intervention in children with phonological disorder and specific language disorder<sup>10,11</sup>.

Due to the scarcity of validated instruments, especially in Brazil, to quantify speech alterations specifically in hearing impaired children, we question the use of standardized instruments to measure phonological alterations in children with normal hearing that could also be used to evaluate children hearing impaired.

The objective of this research was to obtain and compare the percentage of correct consonants (PCC) in hearing impaired children with Cochlear Implants and / or hearing aids, in a 12-month interval with speech-language intervention using the aural approach. In addition, we sought to verify the influence of frequency on therapy, from the time of identification of the hearing impairment and the time of use of the hearing device. It was also the objective of this study to trace the participants' profile, collecting data such as age, gender, time of therapy, time of adaptation of the hearing device and time of identification of the hearing loss.

## METHODS

This is a longitudinal observational study. The study was conducted at the educational audiology clinic of a school hospital of the public health network.

After the analysis and approval of the Research Ethics Committee of the Federal University of São Paulo, under the number of protocol 192041/13, the persons responsible signed the Free and Informed Consent Term. For this study, 19 individuals participated, six of whom were cochlear implantees and 13 hearing aids users, who were evaluated in two moments, with a minimum interval of 12 months. Inclusion criteria were: congenital sensorineural hearing loss, between three and 11 years old, being a hearing aid user with binaural adaptation or unilateral cochlear implant user with bimodal stimulation, enrolled in speech therapy with aural approach for at least twelve months, and do not present other associated pathologies.

The procedures of the study involved: protocol study before the applications of the tests, interview with the responsible ones, application of the ABFW and calculation of the PCC, being these realized in two opportunities with interval of 12 months.

It should be noted that the therapy sessions were individually held for 45 minutes and were offered twice

a week for all children, thus, in the 12-month period, 75 therapy sessions were offered for each child. Regarding the therapeutic approach used, all children were exposed to the aurial approach.

### Protocol study before the first application of the test

This protocol study was used to demographic survey of the possible participants of this research, aiming to obtain data regarding: age, degree of hearing impairment, type of hearing loss, type of prosthesis or implant, time of therapy, time to identify the disability the time of adaptation of the prosthesis and / or implant and the date of the last audiological evaluation.

### Protocol study prior to the second test application

The purpose of this study was to verify the modification of the auditory device, that is, to verify the change of the model and brand of the hearing aid or speech processor of the cochlear implant between evaluation 1 and 2, recent audiometry, daily use time of the hearing device (based on auditory device companies' software) and based on the family report, as well as the percentage of patients attending therapy sessions. It should be noted that no changes were observed in the model and / or brand of the devices (Speech Processor of the Cochlear Implant or hearing aids during the established period, that is, 12 months). Thus, during the collection period, the only changes were made in the electroacoustic parameters of the devices.

### Interview

Respondents answered a questionnaire with questions regarding the child's identification, clinical history and motor and language development.

### Correct Consonant Percentage Index (PCC)

The PCC index was calculated from the application of ABFW, a Children's Language Test in the areas of phonology, vocabulary, fluency and pragmatics, which includes figures and protocol for annotating the child's responses at the time of evaluation. The test is indicated for children aged between 2 and 12 years. The tests of phonology were applied: imitation, naming and spontaneous speech, in this order<sup>12</sup>.

In the phonology test, figures were presented so that the child could name them. If the child did not name the figure, the evaluator named it and, after five

figures, the evaluator returned to the unnamed figure and asked the child to be nominated again.

In the imitation test, the child was instructed to repeat the words spoken by the evaluator. When the child did not imitate any words, they were presented once more at the end of the test.

The spontaneous speech was provoked directly or indirectly. In direct conditions, questions were used to evoke the answers, this condition was proposed for older children (examples: what is the favorite subject of the child in school, what are the favorite games, the name of their classmates, among others related to daily life of child). With the younger children (under the age of five), the indirect conditions were used, that is, the examiner interacted with the child in play situations with miniature objects that facilitated the collection of a five-minute speech sample. All speech samples were recorded in video to facilitate transcription.

### Calculation of the PCC Index

The Percentage of Correct Consonant Index was calculated by the number of correct consonants of the speech sample obtained from the three ABFW tests. The result was obtained by dividing the correct consonants by the total consonants of the sample (correct consonants plus incorrect consonants), multiplying the result by 100. In order to calculate the PCC, only the consonants that the child intended to produce in the word, and only the consonants of the words actually produced are counted.

In the calculation of the PCC only the consonants that the examiner was certain about the correct production were considered, so partially or completely unintelligible words were excluded from the sample, based on the analysis of the recorded video.

Were considered errors:

- Target consonant erasures;
- Substitutions of another sound for a target consonant;
- Distortions of a target sound;
- Adding a sound to a correct or incorrect target consonant.

The ABFW test phonology tasks were applied to the selected children and reapplied with a 12-month interval in the same children. In this way, there was no composition of groups, since the children were compared individually, with themselves, in two different moments.

## Statistical Method

To verify if there were statistically significant differences between the PCC indices, among the applications, non-parametric tests were used, since the data set has a low sampling rate (less than 30 subjects). The following tests were used: Two-Proportion Equality Test, Mann-Whitney Test, Wilcoxon Test, Spearman Correlation, Correlation Test, and Confidence Interval for Mean.

A significance level of 5% (p-value 0.05) was established for this study. The results with statistically significant difference were highlighted by the asterisk (\*) symbol.

## RESULTS

Table 1 shows the main descriptive measures regarding age, time of therapy, time of adaptation of the hearing device and time of identification of hearing loss, all in years.

Regarding the gender variable, it was verified that there was no statistical difference in the composition of the sample. However, more boys (63.2%) than girls (36.8%) were evaluated.

From the data collected, it was observed that the children of this sample presented degrees of hearing impairment varying from moderate to profound, demonstrating a higher occurrence of the deep degree (Table 2).

**Table 1.** Descriptive analysis of time and age variables (years)

Descriptive (years)	Age	Therapy time	Adaptation time	Time of HL identification
Average	6,6	3,5	4,2	1,8
Median	5,6	3,0	3,4	1,7
Standard deviation	2,4	2,3	2,4	0,8
CV	36%	66%	57%	44%
Q1	4,7	1,8	2,4	1,2
Q3	8,6	4,8	5,8	2,5
Min	3,8	1,0	1,3	0,8
Max	11,2	8,8	8,3	3,2
N	19	19	19	19
IC	1,1	1,0	1,1	0,4

Legend: Device Adaptation Time Hearing (Hearing Aid or Cochlear Implant); Time of HL (hearing loss) identification

**Table 2.** Distribution of the degree of hearing loss (n = 19)

Degree	N	%
Moderate Bilateral	2	10,5%
Moderate to Severe Bilateral	3	15,8%
Deep right ear e Moderate left ear	2	10,5%
Moderately Severe right ear e Severe left ear	2	10,5%
Severe to Profound bilateral	3	15,8%
Profound Bilateral	7	36,9%
Total	19	100%

PCC indexes were compared by test and the general mean index, after 12 months. The initial evaluation was called Av1 and the reassessment was called Av2. It was observed that all comparisons revealed a statistically

significant difference between the moments, using the Wilcoxon test, demonstrating an improvement in the percentage of correct consonants in all tests and in the mean of the CCP (Table 3).

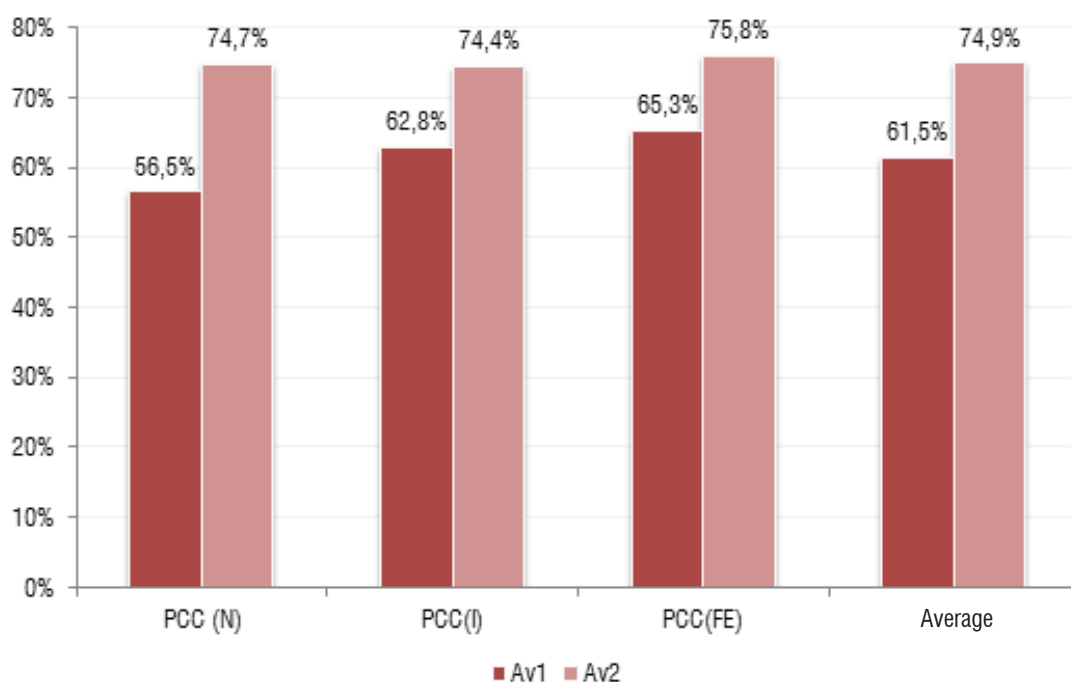
**Table 3.** Descriptive Measures of Correct Consonant Percentages in Evaluations 1 and 2

		Average	Median	Standard deviation	Q1	Q3	N	IC	P-value
PCC (N)	Av1	56,5%	57,1%	29,0%	35,8%	78,2%	19	13,0%	<0,001*
	Av2	74,7%	76,6%	17,3%	62,8%	90,0%	19	7,8%	
PCC(I)	Av1	62,8%	58,1%	20,5%	46,4%	76,3%	19	9,2%	<0,001*
	Av2	74,4%	75,5%	15,3%	61,3%	87,6%	19	6,9%	
PCC(FE)	Av1	65,3%	63,2%	21,4%	50,0%	86,3%	19	9,6%	0,001*
	Av2	75,8%	70,6%	15,9%	64,4%	89,8%	19	7,2%	
Average	Av1	61,5%	58,0%	22,4%	42,9%	81,8%	19	10,1%	<0,001*
	Av2	74,9%	74,7%	15,4%	63,0%	88,9%	19	6,9%	

Legend: (N) Appointment; (I) Imitation; (FE) Speaks Spontaneous (Av1) Assessment 1 and (Av2) Assessment 2.  
Statistical method used: Wilcoxon test

The performance of the three tests was compared. Regarding this measure, there was a statistically significant difference in the results of the mean of the PCC indices between the moments demonstrating improvement of the percentage of correct consonants in the reevaluation after one year.

The values of the comparison of PCC index after 12 months of therapy indicated an improvement in the mean index and also in all tests, being the test with the highest percentage of difference between moments, appointment (18.2%) followed by imitation (11.6%) and spontaneous speech (10.5%) (Figure 1).



Legend: (N) Appointment; (I) Imitation; (FE) Speaks Spontaneous (Av1) Assessment 1 and (Av2) Assessment 2.

**Figure 1.** Comparative percentages of PCC considering first and second evaluations

Considering the variables that could influence the results of this study, it was chosen to establish the correlation between the mean increase in CCP and the variables: frequency in therapy, time of use of the hearing device and time of identification of hearing loss.

It was observed that only the frequency in therapy ( $p = 0,035$ ) influenced the increase in PCC. However, the time of use of the hearing aid ( $p = 0,106$ ) and the time to identify hearing loss ( $p = 0,322$ ) did not influence the average performance in this analysis (Table 4).

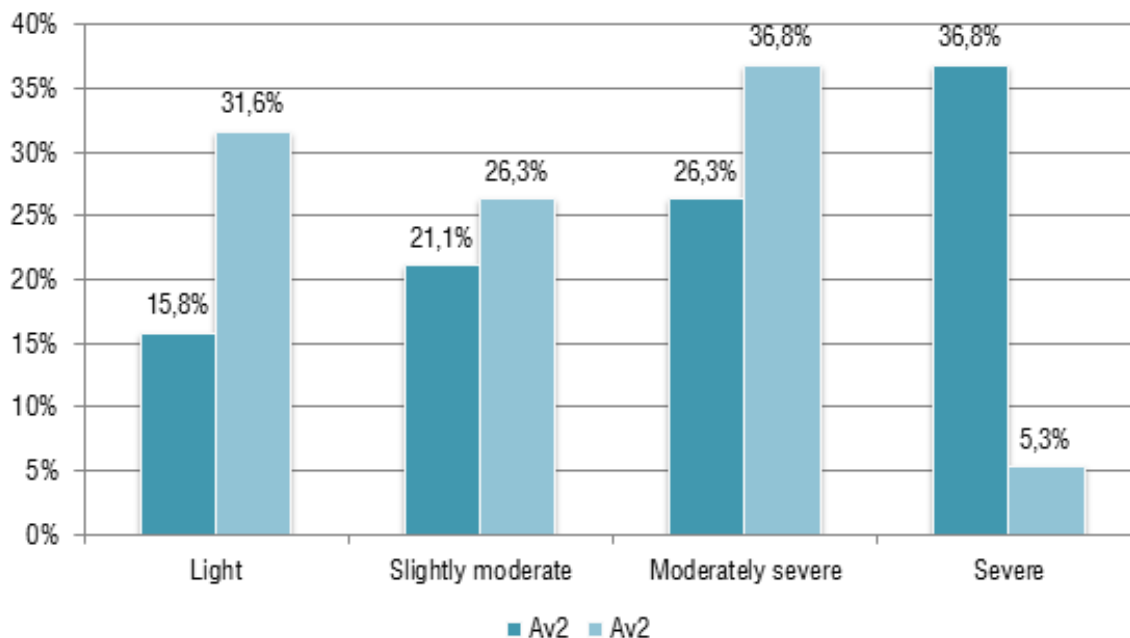
**Table 4.** Correlation of the Percentage Gain of Correct Consonants (mean) with other variables

Variables	PCC (average)	
	Corr (r)	P-valor
Daily use time of the hearing aid	38,2%	0,106
Frequency in Therapy	48,5%	0,035*
Time of Identification of Hearing Impairment	-24,0%	0,322

Statistical method used: Spearman correlation and to validate the correlations was used the Correlation Test.

It should be emphasized that the mean time of daily use of the hearing device was 8.3 hours. In relation to the mean indices (calculated by the average of the three applied tests) obtained individually by the children, the degrees of phonological disorders were classified<sup>6,7</sup> in

the evaluation and in the reevaluation. In this analysis, it was observed that 12 children positively modified the degree of phonological disorder between the evaluations, after intervention. (Figure 2).



Legend: (Av1) Assessment 1 and (Av2) Assessment 2.

**Figure 2.** Comparison of degrees of phonological disorders in two moments, in Evaluations 1 and 2



## DISCUSSION

Regarding the individuals' ages, an average of 6.6 years was obtained and, in terms of the time of identification of the hearing loss, it occurred, on average, at 1 year and 8 months (Table 1). It was observed, therefore, that the time to identify hearing loss is outside of what is considered ideal so that there is no impairment in the development of oral language<sup>1,2</sup>.

Given that hearing impairment causes significant sensory deprivation and hearing impaired children in this study were identified after the first year of life, oral language development and later written language tend to be impaired.

In order to reduce the impact of hearing impairment on communication, it is of great importance that the diagnosis, the adaptation of the hearing device and the beginning of the intervention occur in the first six months of life<sup>2</sup>. In the present study, it was verified that the adaptation of the hearing device occurred on average at 4.2 years old, also far away from the considered ideal time. Some factors can be considered as responsible for the presented data: the devaluation of primary and secondary prevention, the lack of information of the population regarding the importance of the early detection of the hearing deficiency, the reduced participation of the health professionals in relation to the valorization and the referral to Neonatal Hearing Screening. It should also be noted that, mainly in the public sector, there is a slow pace of referrals and long queues for the adaptation of hearing devices and for the beginning of the therapeutic process.

Regarding the time of therapy, an average of 3.5 years was obtained. According to other studies, the time of therapy directly influences the mean performance of the percentage of correct consonants, and the longer the therapy, the better the performance of the children<sup>9</sup>.

Considering hearing impairment degree, children presented different degrees varying from moderate to profound, demonstrating a higher occurrence of the profound degree (Table 2). The impact of hearing loss depends on the extent to which the perception of speech sounds is affected. Aspects inherent in the perception of these sounds, such as detection, discrimination, recognition and comprehension, may be impaired by a decrease in auditory threshold according to the degree and type of hearing loss<sup>13</sup>.

Regarding the comparison of mean PCC index and per test (Table 3), there was a statistically significant difference between the moments. As for the mean PCC

index, there was an improvement of 13.4% after 12 months of intervention.

Appointment task showed a greater percentage of difference between moments when compared to other tests (18.2%). These results may be justified by the type of therapeutic planning and therapeutic strategies used, which often involve the use of illustrative figures, involving the stimulation of visual and especially auditory memory.

The imitation test was the second test with the biggest difference between the evaluations. The visual cues that the interlocutor offer in articulatory production seem to play an important role in phonetic development, but can not be considered as the basis for the phonetic acquisition of hearing impaired children<sup>14</sup>. From this information, we can justify the findings of the present study, since the imitation test was the second test with the highest percentage of PCC improvement after 12 months of therapy. It is noteworthy that the use of the visual lane was stimulated in the therapy sessions, because of this, children may have benefited from the refinement of this resource to improve oral production.

The spontaneous speech test was the test with a lower percentage of improvement. According to other studies, children with phonological disorders of preschool age presented better results in naming and imitation tests than more complex tests of syntactic<sup>15</sup> organization. However, other studies have shown that children may perform better on spontaneous speech tests in relation to imitation and naming because they avoid some phonemes they do not know how to produce<sup>16</sup>.

In the present study, it was observed that, in Av1, hearing impaired children presented better performance in the task of spontaneous speech (65.3%), when compared to other tests, naming (56.5%) and imitation (62.8%). However, after 12 months with phonoaudiological intervention, the percentages of correct consonants of the three tests were very similar: naming (74.7%), imitation (74.4%) and spontaneous speech (75.8).

When comparing the PCC index between the evaluations and the studied variables (Table 4), it was observed that only the frequency in therapy influenced the increase in PCC, and the higher the frequency in the therapy the better the average performance.

From the data of this study, the importance of the identification of the hearing loss and the adaptation of the auditory device in the appropriate time, but the

speech-language intervention and the adherence to the therapeutic process are fundamental, since the attendance in therapy influenced directly in the average performance in the tests appointment, imitation and spontaneous speech, which evaluate the oral language.

After results analysis of the present, it can be inferred that the selected procedure (ABFW Test - Phonology) can be used as an instrument to monitor and guide the course of speech therapy of hearing impaired children.

Lack of data regarding prescriptive gain for adequate amplification, RECD measures, and audibility may be scored as limitations of this study. Unfortunately during the collection of the data of the present research, such procedures were still being routinely inserted in the health service in which the children were accompanied.

There is a need for more research involving the production and speech perception of hearing impaired children, in order to increase the scientific evidences involving certain protocols and paradigms of stimulation.

## CONCLUSION

From the two-way comparison of the PCC index in hearing-impaired children, improvement in all tasks was observed after 12 months of speech-language intervention with the auricular abhorrence. Improvement in the oral language development of these children was directly influenced by attendance in therapy. The time of identification and the time of use of the devices did not influence the PCC indexes.

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