

Systematic Review Revisão Sistemática

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Keywords

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Descritores

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Children's language development after cochlear implantation: a literature review

O desenvolvimento da linguagem da criança após o implante coclear: uma revisão de literatura

ABSTRACT

Aim: review the literature for studies that describe the language development of children after they receive cochlear implants. **Research strategies:** Literature review on the PubMed, Web of Science, Scopus, and Science Direct databases, tracing the selection and critical analysis stages in the journals found and selected. **Selection criteria:** We selected original articles looking at children with cochlear implants, which mentioned language development after surgery. Case studies, dissertations, books chapters, editorials, and original articles that did not mention aspects of oral communication development, perception of sounds and speech, and other stages of human development, in the title, abstract, or text, were excluded. **Data analysis:** A protocol was created for this study including the following points: author, year, location, sample, type of study, objectives, methods used, main results, and conclusion. **Results:** 5,052 articles were found based on the search descriptors and free terms. Of this total, 3,414 were excluded due to the title, 1,245 due to the abstract, and 358 from reading the full text; we selected 35, of which 28 were repeated. In the end, seven articles were analyzed in this review. **Conclusion:** We conclude that cochlear implant users have slower linguistic and educational development than their peers with normal hearing - though they are better than conventional hearing aids users - and they are able to match them over time. There is great variability in the test methodologies, thus reducing the effectiveness and reliability of the results found.

RESUMO

Objetivo: Levantar na literatura a descrição do desenvolvimento de linguagem de crianças usuárias de implante coclear. **Estratégias de pesquisa:** Buscas na plataforma Pubmed e nas bases de dados *Web of Science*, *Scopus* e *Science Direct*, seguindo etapas de seleção e análise crítica dos periódicos encontrados e escolhidos. **Critérios de seleção:** Selecionados artigos originais que abordavam crianças usuárias de implante coclear, nos quais eram mencionados o desenvolvimento de linguagem após a cirurgia. Excluídos artigos de estudo de caso, dissertações, capítulos de livros, editoriais e artigos originais que não referenciavam no título, no resumo ou no texto aspectos de desenvolvimento da comunicação oral, percepção dos sons e da fala e outras fases do desenvolvimento humano. **Análise dos dados:** Foi criado um fichamento protocolar contemplando os seguintes pontos: autor, ano, local, amostra, tipo de estudo, objetivos, métodos utilizados, resultados principais e conclusão. **Resultados:** Encontrados 5.052 artigos a partir da busca de descritores e termos livres. Desses, 3.414 foram excluídos pelo título, 1.245, pelo resumo e 358, pela leitura do texto completo, sendo selecionados 35, dos quais, 28 estavam repetidos. Ao final, sete artigos foram analisados nesta revisão. **Conclusão:** Verifica-se que os usuários de implante coclear apresentam desenvolvimento linguístico e educacional aquém de seus pares com audição normal, porém melhor que os usuários de próteses convencionais, podendo igualar-se a eles com o passar do tempo. Há uma grande variabilidade nas metodologias dos testes, diminuindo, portanto, a efetividade e a confiabilidade dos resultados encontrados.

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INTRODUCTION

New technological advances capable of bringing deaf people nearer to the conditions of those with normal hearing give rise to the need to study language development processes that use these technologies, such as the cochlear implant (CI)^(1,2).

It is not yet clearly known how children using CI organize linguistic information and to what extent this is a critical factor in their language development^(3,4), since the ability of the child to hear speech sounds does not mean that he/she is able to process all of the sound signals and their complex linguistic information⁽⁵⁾.

Recent studies show that children with CI develop language in a different way in terms of the amount of receptive and expressive vocabulary compared to children with normal hearing in the same age group, keeping the same stages of language acquisition expected for children with normal hearing^(6,7).

Nevertheless, the mistaken idea persists that language acquisition and the problems at school faced by a deaf child will be resolved with the use of a cochlear implant^(5,8).

In general, CI use has been associated with better results in terms of auditory perception, language development, and reading, compared to children using conventional hearing aids (PHA). However, the individual benefits of cochlear implants vary considerably⁽⁹⁾.

What is widely observed is an enormous variability in auditory performance gains produced by the implant, which may be explained by a series of factors relating to the user patient and to the technology employed. The patient factors that affect their auditory performance involve deafness etiology, the age in which deafness occurred, the age in which the implant is carried out, the period of sensory deprivation, and the degree of residual hearing. The technological factors involve the type of implant⁽⁷⁾.

Besides the specifics of each patient, it is essential for the team that monitors the child to have possible and tangible benchmarks after surgery, primarily in order to respond to family expectations that arise as a result of the implant procedure.

AIM

This paper aims to review the literature for studies that describe the language development of children after they receive cochlear implants, seeking to establish the possible advances achieved, considering the specifics of the populations studied.

RESEARCH STRATEGIES

For the elaboration of this review, we aimed to answer the following question: What do we know about advances in language development in children after they have cochlear implant surgery? Based on this question, the bibliographical search was carried out using the Pubmed search platforms and Web of Science, Scopus, and Science Direct databases. Descriptors were used (DeCS and MESH) – keywords for retrieving subjects from the scientific literature. The following cross-checks were carried

out in English and Portuguese: cochlear implant (DeCS/MeSH) AND language development (DeCS/MeSH); cochlear implant (DeCS/MeSH) AND vocabulary (DeCS/MeSH); cochlear implant (DeCS/MeSH) AND education (DeCS/MeSH); cochlear implant (DeCS/MeSH) AND writing (DeCS/MeSH); cochlear implant (DeCS/MeSH) AND vocabulary (DeCS/MeSH); cochlear implant (DeCS/MeSH) AND writing (DeCS); cochlear implant (DeCS/MeSH) AND language test (DeCS/MeSH).

The search was carried out independently by two researchers and the points of conflict were later resolved by a third evaluator. No limit was established regarding the time of publication.

SELECTION CRITERIA

Original articles that looked at children using cochlear implants, in which language development after surgery was mentioned, were chosen as inclusion criteria. Case study, dissertations, book chapters, editorials, and original articles that did not mention, in the title, abstract, or text, aspects of oral communication development, perception of sounds and speech, or that addressed other stages of human development (adolescents, adults, and the elderly), were excluded.

DATA ANALYSIS

The articles found were initially selected by title relevance. Those that met the inclusion and exclusion criteria were then submitted for abstract review, and if they fit the pre-established criteria, were analyzed completely, following the protocol created for this, and generating the protocol analysis table created for this study. In this, the following points were considered: author, location, sample, type of study, objective, methods used, main results, and conclusion (Table 1).

RESULTS

5,052 articles were found based on the descriptor search (DeCS/MeSH). Out of this total, 3,414 were excluded due to title, 1,245 due to abstract, and 358 from reading the whole text; 35 articles were selected according to the inclusion and exclusion criteria, however 28 were repeated in the databases, resulting in seven papers being analyzed in this review (Figure 1).

The heterogeneity of the studies allowed for statistical analysis (meta-analysis), in particular because the study frameworks, the samples, the population ages, and the study objectives were varied. However, despite these differences, important reflections and conclusions can be drawn from this review.

The bibliographic review and analysis of the selected articles reveal interest for detailed documentation on CI users' language development, with emphasis on the pediatric population only beginning after 2000⁽¹⁵⁾. This fact may be explained by the clinical recommendation of CI only having been allowed by the Food and Drugs Administration (federal agency of the Department of Health and Human Services of the United States, responsible for protecting and promoting public health via regulation and

Table 1. Results from the selected studies according to the variables analyzed

AUTHOR(S) YEAR COUNTRY	POPULATION/ SAMPLE	STUDY TYPE	OBJECTIVES	METHODS	MAIN RESULTS	CONCLUSIONS
Zagun and Stumper (2012) ¹⁰	25 chdn D or CIU, in ST; with 12 ♂ and 13 ♀; AI 11 months; CD; 4 chdn with BCI.	Longitudinal	Examine the influence of age at receiving implant and socio-environmental factors in the linguistic progress of children who received CI between 6 months and 3.5 years.	Recording of spontaneous speech in interaction with the parents + questionnaire ① with the parents.	The chdn exhibited considerable vocabulary and grammatical growth over time. In chdn receiving implants up to 24m, progress was + more accentuated earlier, the chdn receiving implants after made it later. Higher levels of maternal schooling were associated with more rapid linguistic progress; age at the time of the implant was not.	A sensitive period (up to 24m) for language learning, the maternal-infant language environment contributes more crucially to their linguistic progress than age at the time of implant.
Iwasaki et al. (2012) ¹¹	190 children, with 60 (31.6%) CIU, 128 (67.4%) were CIU and PHA and 2 (1.1%) were BCIU.	Longitudinal	Investigate a large variety of factors that influence hearing, speech, and lgg development with CI.	Evaluation set for language development in Japanese children with hearing deficiencies (ALADJIN).	The maximum speech distinction score, and speech intelligibility classification among CI users was significantly ($p < 0.01$) better than among the UCIU and PHA. The STA and TQAUD scores among UCI and PHA were significantly ($p < 0.05$) better than those for UCIU. A high correlation ($r=0.52$) was found between the CI age and highest distinctive speech scores. The speech and lgg test scores among chdn receiving implants before 24m have been better than those for chdn receiving implants after 24m.	The CI was effective for the development of language in HD Japanese chdn and early CI was more effective for the vocabulary and syntax production results.
Ostojić et al. (2011) ¹²	30 chdn from 4 to 7y, split into three groups: E1 - 10 D chdn with CIU; E2 - 10 D chdn with PHA and C 10 NH chdn, all the same age. All the D chdn had severe and extensive CD and are in ST.	Cross-sectional	Evaluate the influence of improved auditory perception due to CI in abstract word comprehension in chdn, in comparison with chdn with HD with PHA and chdn with NH.	Vocabulary test ②	The general results for the whole test (100 words) showed a significant difference in favor of NH in comparison with chdn with HD. The child with NH successfully described or defined 77.93% of a total of 100 words. The success rate for the chdn with CI was 26.87% and for chdn with PHA was 20.23%.	Abstract Word tests showed a SS difference between the CI and the chdn with PHA (Mann Whitney U test, $p=0.019$) which implies a considerable advantage of CI over PHA in relation to successful speech development among pre-lingual deaf children.

Captions: CI → cochlear implant; D → deaf; chdn → children; CIU → unilateral cochlear implant user; BCIU → bilateral cochlear implant user; ST → speech therapy; ♂ → boys; ♀ → girls; AAI → average age for receiving implant; CD → congenital deafness; BCI → bilateral cochlear implant; Questionnaire ① → (Germanic adaptation of "MacArthur-Bates Communicative Development Inventories") with Transcription according to "the Child Language Data Exchange System"; PHA → personal hearing aid; HD → hearing deficiency; NH → normal hearing; Vocabulary test ② → Vasić S. Art of speech, exercizes and tests of speech. Belgrade: Beogradski izdavačko-grafički zavod; 1980.(Serbian); SS → statistically significant; NSD → neurosensory deafness; LEAQ → LittleEARS Auditory Questionnaire was used to analyze the children's auditory development; Questionnaire for the parents Elfra-1 → which was developed for detecting early language among German children aged 12 months, who were at risk of developing speech and languages problems; PLD → pre-language deafness; Questionnaire for teachers: AMP → evaluation of Teaching Performance and SIFTER → Screening system for Educational Risk segment; SBCI → simultaneous bilateral cochlear implant; FN → field notes; NPMD → neuropsychomotor development; RDLs → Reynell Scales of Development; PBK → word recognition test; ALADJIN → TQAUD, Peabody- revised; PVT -R, SCTAW; WFT and STA

Table 1. Continued...

AUTHOR(S) YEAR COUNTRY	POPULATION/ SAMPLE	STUDY TYPE	OBJECTIVES	METHODS	MAIN RESULTS	CONCLUSIONS
Chramm et al. (2010) ⁽⁶⁾ Germany	5 chdn with NH and 5 with NSD. All the chdn in the 2 nd group were observed for 36 months after the first CI installation. The chdn from the CI group are CD and had received PHA before receiving BCi.	Longitudinal	This study had two aims: (1) to document the auditory and lexical development of D chdn who received the 1 st CI at 16m and the second CI at 31m and (2) compare the results for these chdn with those of chdn with NH.	The auditory development of the CI group was documented every 3m until 2y (auditory age) and for the group with normal hearing, in chronological age. LEAQ + Elfta-1.	In both groups, the chdn exhibited individual auditory and language development patterns. The chdn with CI developed in a different way regarding the amount of receptive and expressive vocabulary in comparison with the NH group. 3 children in the CI group needed almost 6 months to make progress in speech development that was consistent with what would be expected for their chronological age. In general, the receptive and expressive development in all the children in the group with implants increased with time of hearing.	Early identification and early implant are advisable to give children with neurosensory hearing loss a realistic chance of satisfactorily developing receptive and expressive vocabulary and also developing phonological, morphological, and syntax abilities for school life in a stable way.
Wie (2010) ⁽¹³⁾ Norway	42 children: 21 UCI and 21 with NH, monitored in pairs in accordance with sex and chronological age.	Longitudinal	Examine the development of receptive and expressive language in chdn who received SBCI between 5 and 18m, and compare the results with language development in chronological order in chdn of the same age with NH.	The data was collected post CI surgery in check-ups (3, 6, 9, 12, 18, 24, 36, and 48m). LittleEARS questionnaire + Mullen Early Learning Scale + Minnesota Infant Development Inventory.	Cochlear auditory function of UCI in accordance with LittleEARS was comparable to the chdn with NH within 9 months post-implant. The average scores after 9 and 12 months were 31 and 33, respectively, in PLD, against 31 and 34 in the chdn with NH. Receptive and expressive language scores for chdn show that after 12-48 months with CI, 81% had receptive language abilities within the normal parameters and 57% had expressive language abilities within the normal parameters. The number of chdn who scored within the normal range increased with CI experience.	This study showed the ability of PLD chdn to develop complex expressive and receptive spoken language after early BCi appearing promising. Most of the chdn developed language abilities at a faster rhythm than their auditory ages would suggest and over time achieved receptive and expressive language abilities within the normal parameters.
Damen et al. ⁽⁴⁾ United States of America (2006) ⁽⁴⁾	32 UCI chdn, in regular education, with CD or PLD + 37 with NH. 20 children were CD, 12 PLD (<3 years old).	Cross-sectional	Compare the classroom performance of chdn with CI with that of their peers with NH in regular education.	Teachers filled out 2 questionnaires: AMP and SIFTER.	The UCI chdn scored above average in AMP and sufficiently well in all areas, except in that of communication in the SIFTER questionnaire. Class rankings did not differ significantly between pupils with or without CI. In general, the NH group exceeded the UCI group. Classroom performance for chdn with CI was negatively correlated with time of deafness and age at the time of implant. All the longitudinal audiological data for the UCI children exhibited an improvement in speech recognition in open set.	Although the results are encouraging, the CI group scored significantly lower than their peers with normal hearing in most areas of the questionnaire, both for the AMP and the SIFTER. The most important variables for the outcome of this study were implant age and time of deafness.

Captions: CI → cochlear implant; D → deaf; chdn → children; CIU → cochlear implant user; UCIU → unilateral cochlear implant user; BCIU → bilateral cochlear implant user; ST → speech therapy; ♂ → boys; ♀ → girls; AAI → average age for receiving implant; CD → congenital deafness; BCi → bilateral cochlear implant; Questionnaire ① → (Germanic adaptation of "MacArthur-Bates Communicative Development Inventories") with Transcription according to "the Child Language Data Exchange System"; PHA → personal hearing aid; HD → hearing deficiency; NH → normal hearing; Vocabulary test ② → (Vasic S. Art of speech, exercizes and tests of speech. Belgrade: Beogradski izdavačko-graficki zavod; 1980. (Serbian)); SS → statistically significant; NSD → neurosensory deafness; LEAQ → LittleEARS Auditory Questionnaire was used to analyze the children's auditory development; Questionnaire for parents Elfta-1 → which it was developed for detecting early language among German children aged 12 months, who were at risk of developing speech and languages problems; PLD → pre-language deafness; Questionnaire for teachers: AMP → evaluation of Teaching Performance and SIFTER → Screening system for Educational Risk segment; SBCI → simultaneous bilateral cochlear implant; FN → field notes; NPMD → neuropsychomotor development; RDLS → Reynell Scales of Development; PBK → word recognition test; ALADIN → TQAUD; Peabody - revised; PVT -R; SCTAW; WFT and STA

Table 1. Continued...

AUTHOR(S) YEAR COUNTRY	POPULATION/ SAMPLE	STUDY TYPE	OBJECTIVES	METHODS	MAIN RESULTS	CONCLUSIONS
Svirsky et al. (2000) ⁽¹⁵⁾ United States of America	70 chdн were evaluated around 4m before receiving their CI and again 6, 12, 18, 24, and 30m after implant.	Cross-sectional	Compare the Igг development of chdn with PLD UCI and predict language development of these chdn if they had not received the implants. Finally, the measured Igг development from the sample of chdn with CI was compared with the standards obtained for chdn with NH.	RDLs + PBK Scale	The Igг development rate after receiving implants exceeded the expectations for D chdn without implants ($p < .001$), and was similar to that for chdn with NH.	Despite a large amount of individual variability, the best performers in the group with implants appear to be developing an oral linguistic system, based primarily on the auditory entrance, obtained from a Cl.

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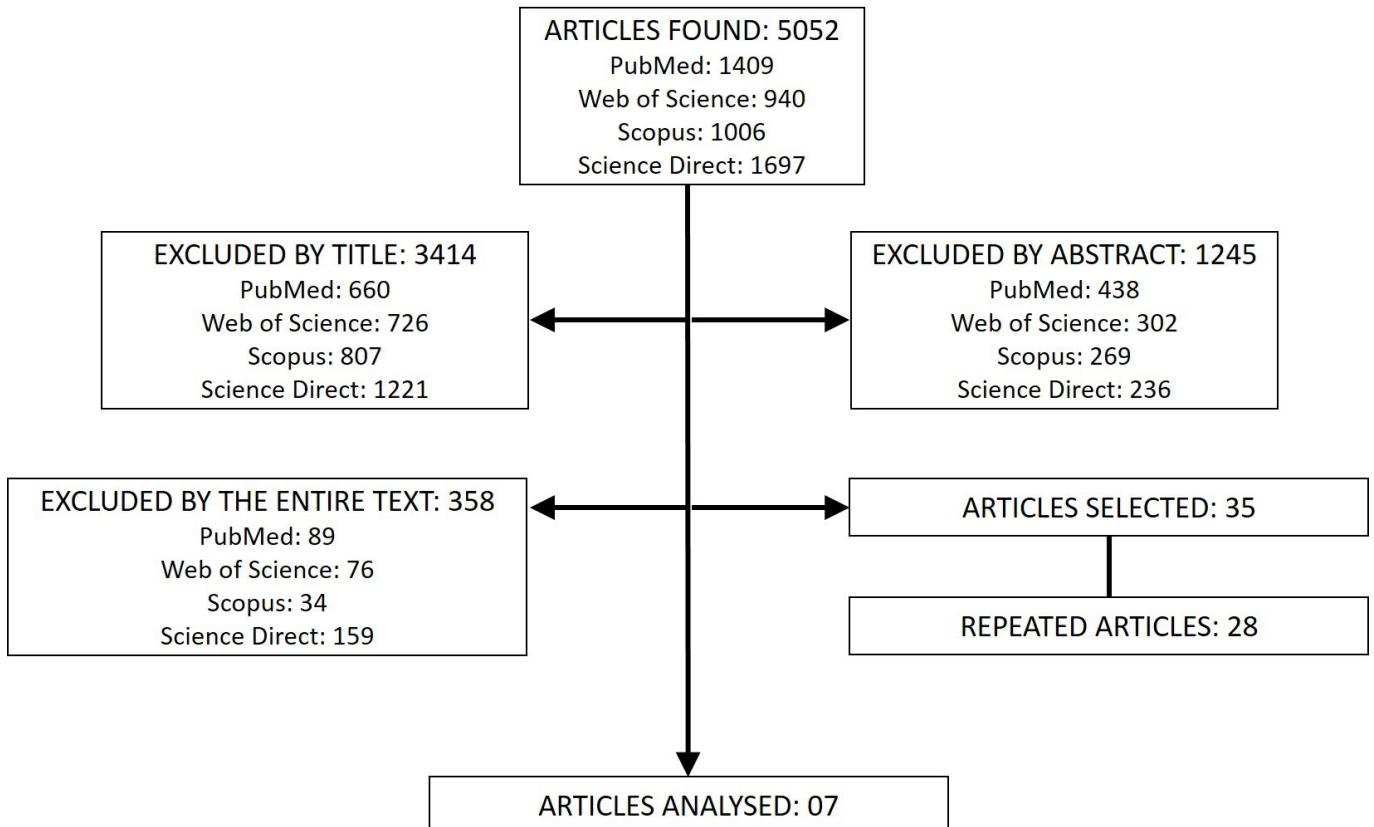


Figure 1. Flowchart of the number of articles found and selected after applying the inclusion and exclusion criteria

supervision of food and product safety) of the US government in 1990⁽⁷⁾.

We can perceive from the analysis of the articles that countries in Europe (Germany, United Kingdom, Serbia, and Norway), Asia (Japan), and North America (United States of America) are producing greater knowledge within this area of interest. This fact reflects the results from pioneering nations in CI surgery; however, the lack of papers carried out in France – a country which always stood out in CI studies – draws our attention, as well as in the Netherlands – a country that carried out the first CI operations in children⁽¹⁶⁾.

The population studied in the articles selected in this review constituted a very heterogeneous sample, with a minimum of ten children⁽⁶⁾ (five CI users and five with normal hearing) and a maximum of 190⁽¹¹⁾ (with 60 unilateral CI users, 128 IC+PHA users, and two bilateral CI users). However, a larger number of studies with samples smaller than 100 individuals^(6,10,12-15) was perceived.

Only one study⁽¹³⁾ used a control group, with the individuals being paired by sex and chronological age. Most of the studies did not specify the children's sex^(6,11,12,14,15).

With regards to study type, four^(6,10,11,13) were longitudinal and three^(12,14,15), cross-sectional; which shows a tendency for choosing longitudinal studies in more recent studies, probably because, in this type of study, it is possible to learn greater details

and carry out monitoring with periodical reevaluations, with it being possible to compare the weighted gains of each patient.

With regards to the evaluation method for verifying language development in children, there was no standard, however at least one questionnaire, which may have been carried out with the children, with the parents, or with the teachers, was used in four^(6,10,13,14) of the articles. Scale evaluation is a procedure that should be thought out with caution, since its classification is quite subjective, generally being more effective when applied by people who are not directly involved in the study. In previous studies, the participation of third parties for this application was not informed, potentially causing bias of interest in the obtained results.

Only three articles used tests (or a battery of tests) with the children, and the lack of conclusions was explained by the difficulty in evaluating small children efficiently, since children have been undergoing CI earlier and earlier.

Despite the richness of detail obtained in the children's spontaneous speech recordings (with subsequent analysis), only one⁽¹⁰⁾ study opted for this strategy. We call attention to it, since it is one of the most recent studies, which may suggest a qualitative change in more current evaluations.

Contrary to common sense, only one⁽¹⁰⁾ study did not verify a connection between linguistic progress and age at the time of implant. This piece of data may be explained by the average age at the time of implant, which was 11 months. The literature^(11,14)

notes that children receiving implants before 24 months exhibit significantly better responses, and with the average age at implant being so young, the gains tend to be similar⁽¹⁷⁾.

The studies that investigated children with normal hearing (NH), PHA users, and CI users, agreed with the pre-existing literature: children with NH exhibit better results than children with CI and the latter present better responses than PHA⁽¹²⁻¹⁵⁾ users. In the longitudinal studies, the receptive and expressive development in all of the children from the CI group increased with time^(6,10,11,13); which was already to be expected, given that auditory experience favors better linguistic performance⁽¹³⁾.

The study which obtained more detailed results for the linguistic gains of children using CI and compared these with the results for children with NH was the study carried out in Norway, since with the LittleEARS questionnaire it managed to show that the cochlear function of CI users was comparable with that of children with NH nine months after surgery.

CONCLUSION

The CI is effective for developing language in children with hearing loss when coupled with speech therapy, obtaining more accentuated results (syntax and vocabulary) the earlier surgery is carried out.

Although the CI studies are encouraging, it is noted that CI users exhibit significantly lower linguistic and educational development than their peers with normal hearing - but better than users of PHA - and are able to match them over time.

The children's receptive and expressive language scores showed that, after 12-48 months with CI, 81% had receptive language abilities within the standard parameter and 57% had expressive language abilities within the standard parameter. The number of children who achieved the normal range increased with increased CI experience.

The review in question showed that there is the possibility and necessity for in depth studies, with the aim of stabilizing and standardizing evaluative and comparative tools in order to provide clarification of language development among this population.

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Author contributions

CGM was responsible for collecting, tabulating, and analyzing the data and elaborating the manuscript; HJS supervised the collection, tabulation, and analysis of the data and orientated the stages of execution and elaboration of the manuscript; AAAC was responsible for collecting, tabulating, and analyzing the data, devising the project, outlining the study, and general orientation of the stages of execution and elaboration of the manuscript; BAMQ was responsible for the analysis of the data and orientated the stages of execution and elaboration of the manuscript.