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Development of auditory skills and oral language throughout the audiological monitoring process of children with hearing impairment

Desenvolvimento de habilidades auditivas e linguagem oral ao longo do processo de acompanhamento audiológico de crianças com deficiência auditiva

Desarrollo de las habilidades auditivas y del lenguaje oral a lo largo del proceso de seguimiento audiológico del niño con discapacidad auditiva

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Abstract

Introduction: The intervention process for infants with hearing loss aims to develop oral language and auditory skills. The effects of a lack of audibility are reflected in language, reading, and writing skills. **Objective:** To analyze the development of auditory skills and oral language throughout the process of audiological monitoring, fitting of electronic devices, and intervention for infants and children. **Method:**

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The group of subjects consisted of ten children with moderate to profound sensorineural hearing loss, users of hearing aids and/or Cochlear Implants. The subjects were divided by audibility criteria: G1 – SII 65 dB up to 35%; and G2 – SII 65 dB >= 54%. Audiological evaluation, device verification, and administration of the IT-Mais, MUSS, LittlEars, and Hearing and Language Categories questionnaires were performed to assess auditory and oral language skills. **Results:** Subjects in G1 performed below expectations regarding skill development, reinforcing the need for CI. The G2 subjects demonstrated improvement in their auditory skills, reaching the instrument's maximum score in the last assessment, as well as demonstrating improvement in oral language skills. The audiological thresholds monitored throughout the study showed changes. **Conclusion:** The validation of the audiological diagnosis process and monitoring of infants and children with hearing loss demonstrated developmental progress using appropriate instruments for the early years of children with hearing loss who are not yet able, due to their age and cognitive development, to take formal speech and language perception tests.

Keywords: Hearing Aids; Hearing Impairment; Hearing Loss; Language Development; Speech-Language Pathology and Audiology.

Resumo

Introdução: O processo de intervenção em bebês com perda auditiva tem como objetivo o desenvolvimento da linguagem oral e suas habilidades auditivas. Os efeitos da falta de audibilidade refletem nas habilidades de linguagem, leitura e escrita. **Objetivo:** Analisar o desenvolvimento de habilidades auditivas e linguagem oral ao longo do processo de acompanhamento audiológico, adaptação de dispositivos eletrônicos e intervenção de bebês e crianças. **Método:** O grupo de sujeitos foi composto por dez crianças com deficiência auditiva neurossensorial de grau moderado a profundo, usuários de AASI e/ou IC. Os sujeitos foram divididos pelo critério de audibilidade: G1 – SII 65 dB até 35% e G2 – SII 65 dB >= 54%. Foram realizadas: avaliação audiológica, verificação dos dispositivos e aplicação dos questionários IT- MAIS, MUSS, LittlEars e Categorias de audição e linguagem para avaliar as habilidades auditivas e de linguagem oral. **Resultados:** Os sujeitos do G1 apresentaram desempenho aquém do esperado em relação ao desenvolvimento das habilidades, reforçando a necessidade do IC. Os sujeitos do G2 demonstraram evolução nas habilidades auditivas, alcançando o teto de pontuação dos instrumentos na última avaliação, bem como demonstraram melhora nas habilidades de linguagem oral. Os limiares audiológicos monitorados ao longo da pesquisa apresentaram mudanças. **Conclusão:** A validação do processo de diagnóstico audiológico e acompanhamento de bebês e crianças com deficiência auditiva demonstrou a evolução do desenvolvimento a partir da utilização de instrumentos apropriados para os primeiros anos de crianças com perda auditiva que ainda não têm condições, pela idade e desenvolvimento cognitivo, de realizar testes formais de percepção de fala e linguagem.

Palavras-chave: Auxiliares de Audição; Deficiência auditiva; Perda auditiva; Desenvolvimento da linguagem; Fonoaudiologia.

Resumen

Introducción: El proceso de intervención para infantes con pérdida auditiva tiene como objetivo desarrollar el lenguaje oral y las habilidades auditivas. Los efectos de la falta de audibilidad se reflejan en las habilidades de lenguaje, lectura y escritura. **Objetivo:** Analizar el desarrollo de las habilidades auditivas y del lenguaje oral a lo largo del proceso de monitoreo audiológico, adaptación de dispositivos electrónicos e intervención para infantes y niños. **Método:** El grupo de sujetos consistió en diez niños con pérdida auditiva neurosensorial moderada a profunda, usuarios de audífonos y/o IC. Los sujetos fueron divididos por criterios de audibilidad: G1 – SII 65 dB hasta 35%; y G2 – SII 65 dB >= 54%. Se realizó evaluación audiológica, verificación del dispositivo y administración de los cuestionarios IT-Mais, MUSS, LittlEars y Hearing and Language Categories para evaluar las habilidades auditivas y del lenguaje oral. **Resultados:** Los sujetos en G1 se desempeñaron por debajo de las expectativas con respecto al desarrollo de habilidades, lo que refuerza la necesidad de IC. Los sujetos de G2 demostraron una mejora en sus habilidades auditivas, alcanzando la puntuación máxima del instrumento en la última evaluación, así

como una mejora en sus habilidades de lenguaje oral. Los umbrales audiológicos monitoreados a lo largo del estudio mostraron cambios. **Conclusión:** La validación del proceso de diagnóstico audiológico y el monitoreo de bebés y niños con pérdida auditiva demostró un progreso en el desarrollo mediante el uso de instrumentos adecuados para los primeros años de vida de niños con pérdida auditiva que, debido a su edad y desarrollo cognitivo, aún no pueden realizar pruebas formales de percepción del habla y el lenguaje.

Palabras clave: Audífonos; Deficiencia auditiva; Pérdida auditiva; Desarrollo del lenguaje; Logopedia.

Introduction

The validation of the prognosis presumed from the initial audiological characteristics of a child with hearing loss is consolidated throughout the rehabilitation process, while non-audiological variables—such as consistent use of hearing aids (HA), limited opportunities for verbal interaction, and socioeconomic factors—directly influence development. One study emphasized the importance of the cross-check process, using audiological data from diagnosis and longitudinal monitoring during intervention, since for the pediatric population rehabilitation can be considered a process of continuous validation[1]. In the case of infants and children, given the multiple variables that may interfere with their development, validation must permeate the entire follow-up and rehabilitation process so that, whenever necessary, new audiological evaluations, adjustments to the physical and acoustic characteristics of the HA and/or cochlear implant (CI), changes in therapeutic approaches, and multidisciplinary referrals are carried out.

The main goal of audiological diagnosis and intervention in infants and children with hearing loss (HL) is the development of oral language and auditory skills. Early and consistent access to the audibility of speech sounds has substantial and lasting effects on language and auditory abilities, particularly when provided within the first months of life[2–5]. Late diagnosis and intervention, as well as inconsistent use of hearing devices, negatively affect vocabulary outcomes, resulting in children performing below age expectations[6].

Objective measures have been used to evaluate children's access to speech, such as the Speech Intelligibility Index (SII), which identifies the amount of audible speech information available. Low SII values may indicate limited access to speech sounds and a potential risk for delayed vocabulary development[7–8,6]. Regular electroacoustic verification of pediatric hearing aids is recommended by the Pediatric Guidelines of the American Academy of Audiology (AAA), ensuring both audibility and comfort[9–10].

Monitoring daily HA use through datalogging is an important tool for both families and professionals during the rehabilitation process, supporting clinical decision-making and family counseling[1,11]. Although literature highlights the importance of consistent HA use, there are still ongoing discussions on how it correlates with speech audibility and comprehension[7]. Recent studies have proposed the concept of auditory dosage as a measure of listening experience, suggesting that higher auditory dosage is associated with better vocabulary outcomes[7,12].

Ensuring consistent use of amplification, family engagement, and a language-rich environment is fundamental in the early stages of therapeutic intervention[13–15]. Monitoring developmental progress supports both speech-language pathologists and families in adjusting expectations and children's prognoses. Assessing language and listening abilities in pre-verbal stages is a challenge for both parents and therapists. Evidence demonstrates that parent questionnaires can help identify developmental milestones and risk factors. Instruments such as IT-MAIS, MUSS, LittlEars, and the Categories of Audition and Language are valuable tools that not only quantify but also identify when development deviates from expected trajectories during the first five years of device use[1,16,4,17].

The use of validated assessment instruments in pediatric follow-up plays a key role in guiding clinical decisions and informing therapeutic adjustments. Therefore, the present study aimed to analyze the development of auditory skills and oral language throughout the audiological follow-up, device fitting, and intervention process in infants and children with hearing loss.

Material and Method

This was a longitudinal interventional study with a quantitative approach, approved by the Research Ethics Committee under protocol no. 5.589.444. In accordance with ethical principles for research involving human participants, parents and/or legal guardians signed an informed consent form.

The study was conducted at the *Centro Audição na Criança – DERDIC*, a Specialized Rehabilitation Center that provides audiological diagnosis for infants referred after failing newborn hearing screening or identified by other services within the municipal health network, up to six years of age. The center offers monitoring of auditory risk indicators, audiological diagnosis, hearing aid selection and fitting, speech-language therapy, and multidisciplinary intervention.

The sample comprised ten children with moderate to profound sensorineural hearing loss[18], users of hearing aids (HA) and/or cochlear implants (CI), diagnosed between 2020 and 2021 and followed up audiologically at the service. These participants were selected from the service's database and included in the study with information collected since their first evaluation.

Participants were divided into two groups according to the SII criterion at 65 dB SPL with HA at the time of initial diagnosis[19]:

- Group 1 (G1): SII 65 dB up to 35% (n=5)
- Group 2 (G2): SII 65 dB equal to or greater than 54% (n=5)

Data were collected from medical records and the CeAC/DERDIC database, covering evaluations from 2020 to 2024. The procedures and instruments included:

1. Periodic Audiological Assessment: Electrophysiological (ABR, OAE), electroacoustic, and behavioral measures (immittance, behavioral observation, Visual Reinforcement Audiometry – VRA, or Conditioned Play Audiometry).
2. Hearing Aid Verification: Application of the prescriptive rule *Desired Sensation Level* (DSL v5) and determination of SII (55 dB, 65 dB, 75 dB) with and without HA.
3. Hearing Aid Fitting Data: Average daily use, device function, and battery verification.
4. Auditory Dosage: Calculated using the equation that combines the number of daily hours of HA use, weighted by SII with HA, and the hours without HA, weighted by unaided SII. Non-use time was calculated as 24 h minus daily use[12,9].
5. Assessment Instruments for Auditory and Language Skills:
   - IT-MAIS (*Infant-Toddler Meaningful Auditory Integration Scale*)
   - LittlEars Auditory Questionnaire[20]
   - MUSS (*Meaningful Use of Speech Scale*)
   - Hearing Categories (Geers)[21]
   - Language Categories (Bevilacqua)[22]

G1 underwent three evaluations (2022, 2023, 2024), and G2 underwent four evaluations (two in 2022, one in 2023, and one in 2024). IT-MAIS and MUSS scores were analyzed according to Comerlatto markers[4], as well as LittlEars[20].

To analyze differences between baseline (t0) and the final evaluation (t4), the Wilcoxon test for paired samples was applied, with effect size (r) calculation. Scatter plots were used to explore relationships between measured values and chronological age. All analyses were performed using R software (v. 4.3.2), with significance set at $p < 0.05$.

Results

The subjects were monitored over a four-year period in the hearing rehabilitation service, and the evaluation results comprise the service's database. Table 1 presents the sociodemographic and audiological characteristics according to the 65 dB SII classification, from the time of data collection for this study up to the subjects' developmental assessment.

Among the variables analyzed, the 65 dB SII showed statistical significance ($p = 0.004$), indicating a significant difference between the two groups regarding audibility. With respect to audiological diagnosis and characterization of hearing loss, all subjects included in the analysis presented sensorineural hearing loss.

In **G1** (profound hearing loss, 65 dB SII with a mean of 26.2% at the last verification), none of the subjects had sufficient audibility for speech sounds to support oral language development with the use of HAs. For this reason, families were counseled regarding rehabilitation and intervention possibilities, and during the process, three children underwent cochlear implant surgery at different ages. All G1 subjects scored below standard developmental levels in all instruments applied for the assessment of auditory and language skills, as a consequence of the lack of audibility.

Table 1. Sociodemographic and audiological characteristics of the subjects according to the 65 dB SII classification (n = 10).

Variable	Total	G1	G2	P Value
Age at diagnosis (months) Mean (SD)	4.7 (3.83)	5.02 (5.06)	4.2 (2.58)	0.935
Current chronological age (months) Mean (SD)	40.6 (6.85)	43.4 (8.32)	37.8 (4.08)	0.199
SII 65 dB (better ear) Mean (SD)	46.4 (23.37)	26.2 (6.14)	66.6 (13.08)	**0.004***
Sex				
Female	20% (2)	0 (0)	40% (2)	
Male	80% (8)	100% (5)	60% (3)	
Degree of hearing loss				
Profund	50% (5)	100% (5)	0 (0)	
Severe	20% (2)	0	40% (2)	
Moderate	40% (3)	0	60% (3)	
Socioeconomic level				
B2	30% (3)	40% (2)	20% (1)	
C1-C2	50% (5)	60% (3)	40% (2)	
D-E	20% (2)	0 (0)	40% (2)	

Source: Master's thesis by Dayane Rainato, 2025.

In **G2** (65 dB SII with a mean of 66.6% at the last verification), according to the numerical analysis of the subjects' mean audiological thresholds, S7 and S9 showed threshold variations > 20 dB when comparing the first and last audiological evaluations, which were considered as threshold deterioration. S6 also presented a significant change in the first visual reinforcement audiometry compared with the ABR and subsequent audiograms. Based on the numerical analysis (Table 2), it is possible to observe changes in the 65 dB SII of the better ear in S9, which decreased from 72% to 47%, leading to a change in audibility category. Subjects S7, S8, and S10 had the best dosage levels at the last evaluation compared with their peers, although still below the desirable level for consistent use.

Table 2. Values of 65 dB SII, record of daily hours of HA use, and calculation of auditory dosage since diagnosis and throughout audiological follow-ups for G2 subjects.

	SII 65 (1)	Best DL (1)	Auditory dosage (1)	SII 65 (2)	Best DL (2)	Auditory dosage (2)	SII 65 (3)	Best DL (3)	Auditory dosage (3)	SII 65 (4)	Best DL (4)	Auditory dosage (4)
S6	0.54	0.30	1.52	0.54	3.90	3.09	0.48	0.00	1.61	0.66	5.00	4.45
S7	0.61	9.60	5	0.61	10.30	5.17	0.68	11.20	6.17	0.63	12.80	5.98
S8	0.67	2.20	3.38	0.67	2.10	3.33	0.75	0.00	1.83	0.77	6.90	6.14
S9	0.72	0.90	2.13	0.72	9.30	6.16	0.6	10.40	5.13	0.47	11.20	4.16
S10	0.85	7.00	6.52	0.85	3.90	4.45	0.83	8.50	7.15	0.8	8.80	6.94

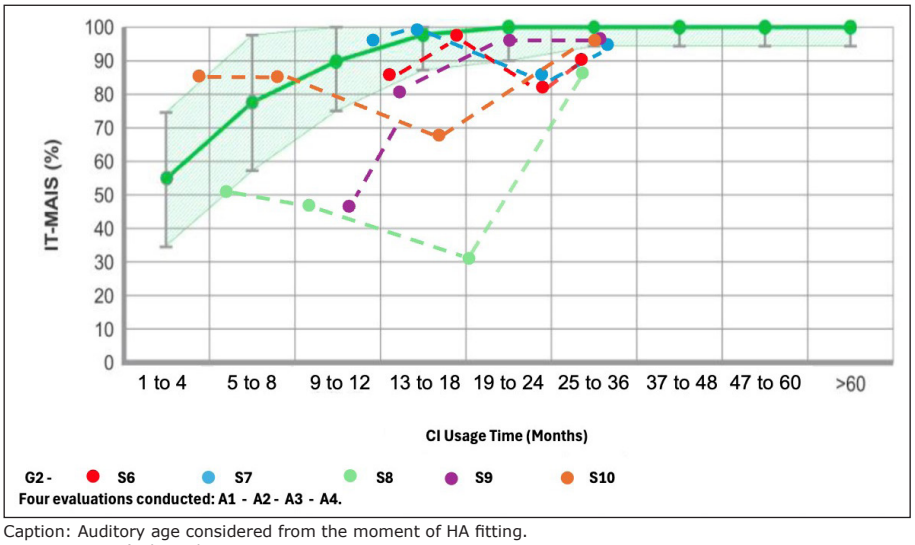
Source: Master's thesis by Dayane Rainato, 2025.

Table 3 presents the results of auditory skills (IT-MAIS, LittlEars) and auditory dosage for G2. Figure 1 shows the IT-MAIS results according to Comerlatto's clinical markers in relation to auditory age, that is, the onset of amplification use. Figure 2 presents the auditory skills assessed by the LittlEars questionnaire over time for G2 subjects. The results demonstrate that all G2 subjects approached the ceiling in the last evaluation.

Table 3. Results of four auditory skills assessments (IT-MAIS and LittlEars) of G2 subjects in relation to auditory dosage.

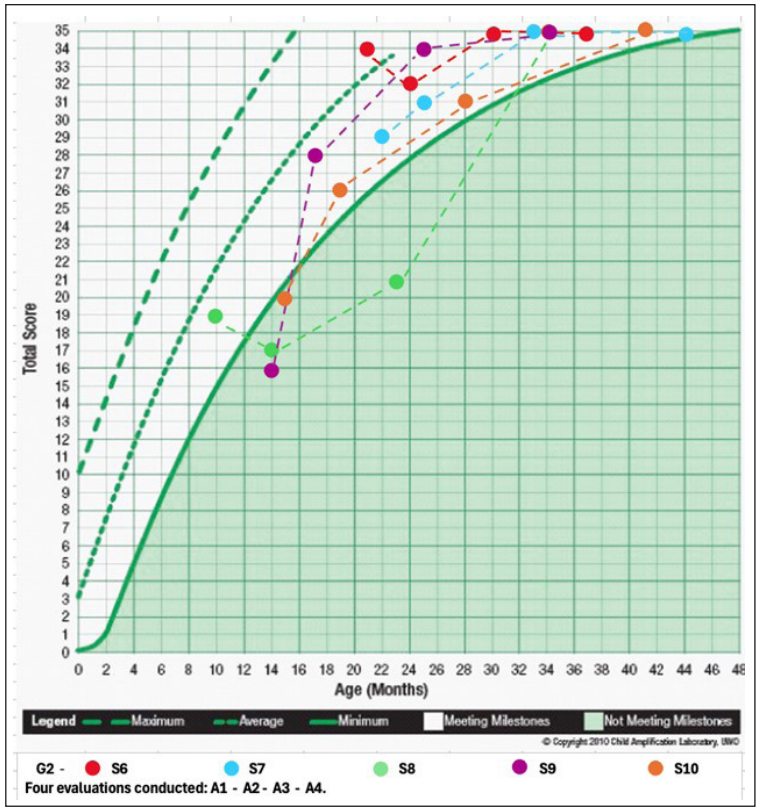
	Dosage 1	LittlEars 1	IT-MAIS 1	Dosage 2	LittlEars 2	IT-MAIS 2	Dosage 3	LittlEars 3	IT-MAIS 3	Dosage 4	LittlEars 4	IT-MAIS 4
S6	1.52	34	85	3.09	32	97.5	1.61	35	80	4.45	35	90
S7	5.00	29	97.5	5.17	31	100	6.17	35	85	5.98	35	95
S8	3.38	19	57.5	3.33	17	50	1.83	21	30	6.14	35	87.5
S9	2.13	16	50	6.16	28	80	5.13	34	97.5	4.16	35	97.5
S10	6.52	20	85	4.45	26	82.5	7.15	31	72	6.94	35	95

Source: Master's thesis by Dayane Rainato, 2025.



Caption: Auditory age considered from the moment of HA fitting.
Source: Master's thesis by Dayane Rainato, 2025.

Figure 1. Results of auditory skills from the IT-MAIS questionnaire over time for G2 subjects, according to the clinical markers proposed by Comerlatto (2015).



Source: Master's thesis by Dayane Rainato, 2025.

Figure 2. Results of auditory skills from the LittlEars questionnaire over time for G2 subjects.

According to the instrument's normative curve, it was observed that all subjects reached the ceiling score in the last evaluation.

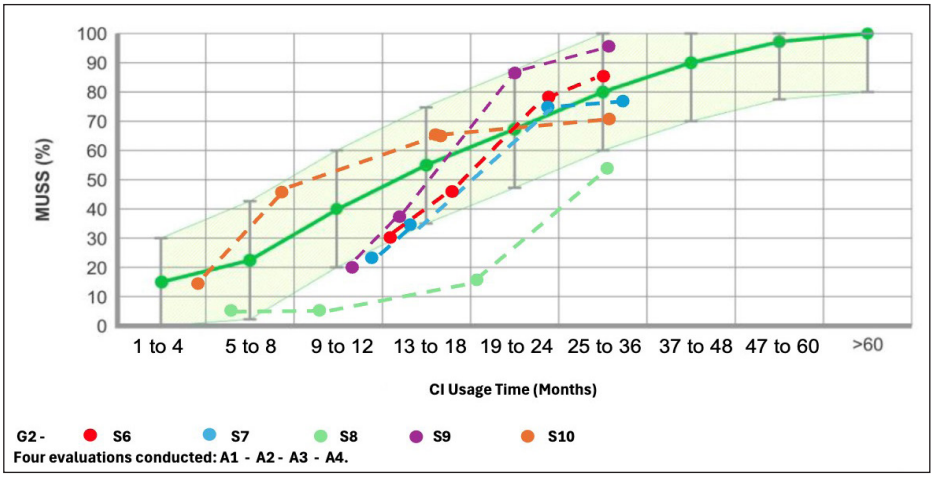
Table 4 presents the analysis based on the auditory and language categories in which the subjects were classified by the researcher. Subjects S6 (auditory dosage 4.45) and S10 (auditory dosage 6.94) were classified as auditory category 5, in which the child identifies words through consonant recognition and differentiates words within a closed set that share the same vowel sound but differ in consonants. The other three subjects were still classified as category 4, in which the child identifies words through vowel recognition and differentiates words within a closed set that differ primarily in vowel sound. Regarding the language category, except for S6 (Category 4), the other subjects were classified as Category 3.

Table 4. Results of auditory and language categories over time for G2 subjects.

Subjects	CAT AUD (1)	CAT LGG (1)	CAT AUD (2)	CAT LGG (2)	CAT AUD (3)	CAT LGG (3)	CAT AUD (4)	CAT LGG (4)
S6	3	2	3	3	4	3	5	4
S7	2	1	3	2	4	3	4	3
S8	1	1	2	1	2	1	4	3
S9	2	1	2	1	3	2	4	3
S10	2	1	3	2	3	3	5	3

Source: Master's thesis by Dayane Rainato, 2025.

Figure 3 shows improvements in oral language skills for G2. S9 obtained the highest final score, and S8, although presenting results below the clinical markers, showed growth in the last evaluation.



Caption: Auditory age considered from the moment of HA fitting.
Source: Master's thesis by Dayane Rainato, 2025.

Figure 3. Results of language skills from the MUSS questionnaire over time for G2 participants, according to the clinical markers proposed by Comerlatto (2015).

Discussion

The objective of this study was to analyze the development of auditory and oral language skills during audiological follow-up, using parent questionnaires to validate diagnosis, device fitting, and intervention for infants and children with hearing impairment. Periodic assessment allows comparison with the expected development for each child according to their audiological diagnosis, ensuring that therapeutic strategies are constantly calibrated and adjusted.

Participants in G1, with profound hearing loss and SII < 35%, experienced difficulties in acquiring oral language due to insufficient audibility. Three participants underwent cochlear implantation (CI), and two were referred to use Brazilian Sign Language (LIBRAS). Despite referral for CI before the first year of life, factors such as family language barriers, cochlear malformation, and behavioral alterations influenced the intervention process, surgical outcomes, and results. Literature indicates that associated impairments can affect the oral language performance of cochlear implant users. In this context, a recent study revealed a complex set of sensory, neurocognitive, and social variables that contribute to speech and language development after cochlear implantation in pre-lingually deaf children. The authors suggest that individual executive functions may influence the success of oral language development in implanted children.

In G2 (initial SII ≥ 54%), audiological follow-up revealed threshold changes in S9, with deterioration and a decrease in SII (72% to 47%), highlighting the importance of ongoing monitoring and the cross-check principle. Consistency in amplification use, as reflected in datalogging, was challenging. By the end of the study, only S7 and S9 used HAs for more than 10 hours/day. Recent studies suggest that auditory dosage (considering SII with/without HAs and usage consistency) is a better predictor of language development than mere device usage hours. Children with a dosage < 5.3–6.7 may be at risk of delayed language development. In G2, only S10 (dosage 6.94) exceeded this threshold at the last evaluation, but their test results were not the highest in the group, possibly due to low family expectations.

G1 showed seemingly better results in the early auditory skill assessments (IT-MAIS and LittlEars). However, as the infants aged, test scores decreased. These findings align with the literature, which con-

firms that families may hold illusory expectations during the first years of life. As developmental milestones are not achieved, families begin to perceive the effects of hearing loss on development.

Parental perspective in periodic developmental evaluation significantly impacts validation. A recent study indicated that the LittlEars questionnaire can predict the emission of the first word in CI users. Due to the retrospective nature of this research, it was not possible to correlate recent literature findings with the study database.

Participants in G2, the group with better audibility, reached the ceiling in LittlEars and mostly in IT-MAIS, according to the benchmarks established by Comerlatto and Moeller regarding the benefits of early audibility. S8 showed progress following increased maternal engagement and auditory dosage, reinforcing the importance of an active family role in the intervention process. Development required the multiprofessional team's commitment to ensure families adhered to intervention, amplification use, and rehabilitation attendance. Observing HA usage records, two participants (S6 and S8) remained below the desired level, and regarding auditory dosage, only S10 reached an adequate value.

Oral language outcomes assessed by MUSS in G2 remained within the expected range for auditory age for all participants, except S8. However, clinical markers were developed for CI users, not HA users, which may have been a limitation of this study. S9 achieved 95% of the total test score in the final evaluation, and observations in the classroom confirmed spontaneous speech use in daily routines. Nevertheless, spontaneous speech consisted mostly of routine vocabulary, with difficulty understanding open-set dialogues. Even with maximum test scores, continued speech-language intervention and implementation of new protocols for oral development parameters from age three remain necessary.

As various studies indicate, factors such as SII, HA usage hours, and speech-language therapy, when combined, are determinants of language development. Individually, they may not explain individual characteristics, and this study suggests they should be analyzed together. Future research using oral language protocols designed for HA users may contribute new parameters to guide family and therapist expectations.

Final Considerations

Analysis of auditory and oral language skill development in the children followed in this study revealed distinct trajectories directly related to audibility provided by electronic devices. G1, with restricted audibility (SII 65 dB < 35%), performed below expected levels in language development, reinforcing the indication for cochlear implantation to enable adequate linguistic progress. In contrast, G2 (SII 65 dB ≥ 54%) demonstrated significant progress in auditory and oral language skills, with most participants reaching maximum scores on auditory questionnaires at the final evaluation. Continuous monitoring proved crucial, as variations in auditory thresholds were observed over time in some participants, directly impacting audibility and emphasizing the need for ongoing therapeutic plan adjustments.

Longitudinal validation of the diagnostic and follow-up process should employ instruments appropriate for early developmental years. Parent questionnaires proved suitable. Despite the small sample, qualitative analysis indicated improvement in auditory and language skills, and periodic assessments were important for adjusting therapeutic strategies. Clinical markers developed for CI users were useful in defining developmental parameters for HA users.

Findings indicated that consistent amplification use must be monitored, given observed HA use variability. This measure informs the calculation of auditory dosage, which considers SII with and without HAs, providing a more accurate measure of the child's access to speech sounds over time. Follow-up of children in this study suggests that longitudinal research is important to deepen understanding of the effect of audibility on language and speech perception development, identify intervening variables, and guide the development of family support strategies.

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