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Exploring disparities in oral health: a comparative study of cochlear implanted and normal-hearing children

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Abstract

Background Hearing loss is known to impact multiple aspects of a child's development, including communication, social interaction, and overall well-being. Among these, oral hygiene represents a critical yet often overlooked component. Given that oral health is closely linked to overall wellness and socio-emotional well-being, and especially when maintaining optimal oral health, it is essential to investigate the specific challenges encountered by children with hearing impairment, particularly those using cochlear implants (CIs), This study aimed to investigate differences in oral hygiene and dental health between cochlear-implanted (CI) and normal-hearing (NH) children.

Method Forty CIs (25 girls, 15 boys) and 44 NH children (22 girls, 22 boys) between the ages of 6 and 13 years who had no neurological or developmental problems participated in this cross-sectional study. The Decayed, Missing, Filled, Total (DMFT/dmft) index and the simplified oral hygiene index (OHI-S) were used to evaluate oral-dental health, and a survey about parental education levels and the demographic characteristics of the participants was conducted. Statistical analyses were performed using IBM SPSS Statistics 29.0.0.0 and Open Epi Program. The normality of the data distribution was assessed with the Kolmogorov–Smirnov test. Non-parametric tests were used for non-normally distributed data, and the Mann–Whitney U test was applied to compare the oral hygiene index between the groups. Categorical variables were compared using the Pearson's chi-square test.

Results Significant differences in oral and dental health were detected between CI and NH children ($p < 0.05$). The mean OHI-S for the CI group was 3.86 ± 1.95, while it was 2.38 ± 0.87 for the NH group. The mean DMFT/dmft scores between the CI and NH participants were 5.48 ± 3.69 and 3.31 ± 2.57, respectively ($p < 0.05$). In the CI group, the parental education level was significantly lower than in the NH group ($p < 0.001$, OR = 11.80). Despite similar hearing, speech, and academic development between CI and NH peers, the impact of lower parental education levels on oral health in CI children was notable.

Conclusion This study revealed that there are significant differences between CIs and NHs in terms of oral health and that mothers' education levels, tooth-brushing habits, and the frequency of dental visits may have yielded crucial contributions to these differences.

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Background

Hearing loss is one of the most common congenital anomalies in children and remains a significant health concern in both developed and developing countries [1–3]. Early diagnosis through routine newborn hearing screening programs plays a crucial role in minimizing the impact of hearing impairment on speech and language development [4]. Depending on regional differences and screening policies, the incidence of congenital hearing loss varies between 1:1000 and 6:1000 live births, and this rate increases throughout childhood due to acquired and progressive hearing loss [4–6].

Oral and dental health problems are recognized as major public health issues worldwide, and affect not only individuals' biological, psychological, and social well-being, but also their communication abilities [2, 7–11].

Maintaining oral hygiene in childhood can be particularly challenging due to factors such as limited manual dexterity, dietary habits, and parental influence [8, 12]. These challenges become even more pronounced in children with disabilities who may face additional barriers to maintaining good oral health [12, 13].

In comparison to their normal-hearing peers, children with hearing impairment often exhibit poorer oral hygiene primarily due to communication difficulties that may hinder effective oral health education and routine dental care [2, 14, 15]. Maintaining oral care in deaf children might be more difficult and thus is often not effective [2, 10, 16]. Studies have reported that hearing-impaired children have a high prevalence of dental caries and a poor oral hygiene index [2, 9–11, 14, 16–19].

Cochlear implantation is currently an accepted treatment option for pediatric patients with severe and profound hearing loss [3, 20]. A cochlear implant (CI) is an effective medical device surgically inserted into the cochlea to stimulate the auditory nerve and improve speech perception. It has been proven to be an effective treatment for children with severe to profound sensorineural hearing loss who receive no benefit from hearing aids [3, 21].

There are studies indicating that the language development, academic performance, and psychosocial development of hearing-impaired children who receive correct, effective, and appropriate auditory rehabilitation are similar to those of normal-hearing children [3, 20, 22, 23]. However, in the literature there is a lack of research investigating oral hygiene and dental health in children using cochlear implants.

To the best of our knowledge, this is the first study to comprehensively evaluate oral hygiene status and dental health in children with cochlear implants. The aim of this study was to examine the prevalence of oral hygiene status and dental caries, which are evaluated among the self-care skills of children with CIs in comparison with those of children with normal hearing. The null hypothesis (H0) was that there would be no significant difference in oral health status between the two groups. By addressing this gap, we aim to provide insights into the oral health challenges faced by children with cochlear implants and how these may have important implications for overall health and quality of life.

Method

Study design

This study was an analytical cross-sectional study conducted between 2021 and 2023 to evaluate oral and dental health in children with cochlear implants (CIs) compared to children with normal hearing (NH). The study included children with profound hearing loss who had undergone cochlear implantation in the prelingual or perilingual period and continued to have regular follow-ups. Oral examinations were performed in a clinical setting, and caregivers completed a structured questionnaire assessing oral hygiene practices and dietary habits.

Subjects

The study included children with profound hearing loss who underwent CI surgery in the prelingual or perilingual period and who continued to have regular follow-ups, and children with normal hearing. A total of 84 children participated in the study; 40 children (15 boys, 25 girls) were in the CI group, and 44 children (22 boys, 22 girls) were in the NH group. All the children were between 6 and 13 years old. The data were collected between the fall of 2021 and 2023, and the final sample included children whose ages ranged from 6 to 13 years at the time of the study.

Inclusion criteria

The cochlear implant (CI) group

- Underwent cochlear implant surgery during the prelingual or perilingual period.
- Presented no history of medical or dental treatment that could affect oral health (e.g., long-term antibiotic use, fluoride therapy, and orthodontic treatment).
- Indicated willingness to participate in the study.
- Had regular and consistent use of the cochlear implant.
- Demonstrated sufficient auditory benefits from the cochlear implant based on routine follow-ups.

- Displayed speech and language development appropriate for age, comparable to children with normal hearing.
- Had parents without hearing or speech impairments.

The normal hearing (NH) group

- Had normal hearing confirmed by audiological evaluation.
- Had no history of medical or dental treatment that could affect oral health.
- Indicated willingness to participate in the study.
- Had parents without hearing or speech impairments.

Exclusion criteria

- Lack of voluntary participation from the child and/or their family.
- Difficulty in cooperating during assessments.
- Presence of a medical condition affecting oral health.
- Neurological or developmental disorders (e.g., cerebral palsy, stroke, cerebrovascular events).
- Genetic or systemic disorders.
- Physical limitations preventing independent tooth brushing.

Cochlear implant group

Patients with normal-hearing parents who had been diagnosed with bilateral profound hearing loss in both ears in the prelingual or perilingual period and who started auditory rehabilitation were included in the CI group. No delay was detected in language, gross motor, fine motor, or personal social development subcomponents in the Developmental Screening Test (DENVER II) administered to the children before and after cochlear implantation until the age of 6 years. In addition, the children were asked whether they had any difficulty listening to lessons or communicating with their friends at school and were asked to rate their scores from 0 to 10; 0 indicated no difficulty and 10 indicated high difficulty. Those with a visual analogue scale (VAS) score of four or below were included in the study. The CI group consisted of children who attended regular schools, similar to children with normal hearing, and who reported that they did not have any difficulty understanding the lessons at school.

The normal hearing group

The normal-hearing group consisted of individuals with bilateral normal hearing, no history of hearing disorders, and without any developmental, neurologic, or systemic disease findings. Each child's hearing threshold at frequencies between 250 and 8000 Hz was 15 dB HL or less. Children with a hearing threshold of 15 dB HL or less were included in this study. Pure tone audiometry was performed using a clinical audiometer (GN Otometrics Madsen Astera2, Taastrup, Denmark) with TDH 39 P headphones for air conduction measurements.

Sound field tests

Sound field thresholds were examined using warble tones from a loudspeaker placed 1 m in front of the children at 0.25, 0.5, 1, 2, 4, and 8 kHz under implantation circumstances using a clinical audiometer (GN Otometrics Madsen Astera2, Taastrup, Denmark). The means of the free-field hearing thresholds at 0.5, 1, and 2 kHz; 1, 2, and 4 kHz; and 0.5, 1, 2, and 4 kHz were defined as FFA_1, FFA_2, and FFA_3, respectively. The free-field test results of the CI group included in the study were within the normal range.

Case report form

Before the examination, a structured questionnaire was administered to parents to assess oral health-related behaviors, including toothbrushing frequency, timing of brushing, use and type of toothpaste, brushing duration, age at which brushing began, frequency of toothbrush replacement, dental visit history (whether they had visited a dentist, the frequency of visits, and the time since the last visit), presence of gingival bleeding, and consumption of sugary or cariogenic foods (Table 1). Additionally, data concerning family characteristics (the number of children in the family, maternal pregnancy age, gestational age at birth, parental education levels) and hearing-related factors for children with hearing loss (age at diagnosis, initiation of auditory rehabilitation, and duration of rehabilitation) were collected.

This questionnaire was designed as a structured Case Report Form (CRF) to obtain sociodemographic and behavioral data. Since it was created specifically for data collection rather than for assessing a psychological or clinical construct, formal validity and reliability testing were not required. However, in order to ensure clarity and relevance, its content was developed based on the existing literature and expert opinions in the field [24–26].

Oral examination

Oral and dental examinations of both groups (CI and NH) were performed in a clinical setting under refractor light using an examination tool (mirror probe). The caries determination method recommended by the World Health Organization (WHO) was used to determine the number of decayed, filled, and missing teeth due to caries [27]. Decayed, Missing (due to caries), Filled Teeth/Surfaces (DMFT), (D: decay, M: missing, F: filling, T: total) were used for permanent teeth, and dmft (d: decay, m: missing, f: filling, t: total) was used for deciduous teeth.

Table 1 Oral health behavior of the CI and NH groups

		CI (*n* = 40) *n* (%)	NH (*n* = 44) *n* (%)	*p* values	Crude OR	95% CI
Mothers' education level	First school or below	21 (77.8)	6 (22.2)	*$p = 0.000$	**11.80**	**3.20-50.22**
	High school	14 (41.2)	20 (58.8)		2.48	0.75–9.06
	College or above (Ref.)	5 (21.7)	18 (78.3)		1.00	
Fathers' education level	First school or below	19 (65.5)	10 (34.5)	$p = 0.055$	2.68	0.85–8.83
	High school	12 (36.4)	21 (63.6)		0.83	0.27–2.58
	College or above	9 (40.9)	13 (59.1)		1.00	
Period when toothbrushing begins (n)	Preschool (Ref.)	12 (50.0)	12 (50.0)	*$p = 0.008$	1.00	
	Kindergarten	13 (32.5)	27 (67.5)		0.48	0.16–1.39
	Primary School	15 (75.0)	5 (25.0)		2.92	0.80-11.61
Frequency of toothbrushing	Never or rarely	21 (84.0)	4 (16.0)	*$p = 0.000$	**5.91**	**1.19–33.07**
	Once a day	14 (29.2)	34 (70.8)		0.50	0.12–2.05
	Twice a day (Ref.)	5 (45.5)	6 (54.5)		1.00	
Teeth brushing duration	Less than 3 min	35 (49.3)	36 (50.7)	$p = 0.472$	1.55	0.46–5.66
	More than 3 min	5 (38.5)	8 (61.5)		1.0	
Frequency of toothbrush changing	3 months	14 (48.3)	15 (51.7)	$p = 0.692$	1.00	
	6 months	17 (43.6)	22 (56.4)		0.83	0.31–2.21
	1 year or more	9 (56.3)	7 (43.8)		1.37	0.39–4.89
Dentist Examination	Never	9 (90.0)	1 (10.0)	*$p = 0.016$	**12.47**	**1.82–297.3**
	Once	13 (43.3)	17 (56.7)		1.10	0.42–2.86
	Twice or more (Ref.)	18 (40.9)	26 (59.1)		1.00	
Bleeding Gum	Yes	10 (55.6)	8 (44.4)	$p = 0.480$	1.45	0.50–4.31
	No (Ref.)	30 (46.2)	35 (53.8)		1.00	
Consumption of sugar	No (Ref.)	3 (75)	1 (25)	$p = 0.120$	1.00	
	Once a day	15 (40.5)	21 (59.5)		0.25	0.00-2.54
	Twice or more	22 (51.2)	21 (48.8)		0.36	0.01–3.61
Fluoride toothpaste use	Don't know	8 (66.7)	4 (33.3)	$p = 0.057$	1.98	0.54–8.29
	Without fluoride	3 (21.4)	11 (78.6)		0.28	0.05–1.05
	With fluoride (Ref.)	29 (50.0)	29 (50.0)		1.00	

*CI: Cochlear implanted group, NH: normal hearing group, OR: Odds ratio, 95% CI: 95% confidence interval, Ref: references, *$p < 0.05$*

For both permanent and deciduous teeth, 'Missing/missing' specifically refers to teeth lost due to caries, excluding other causes such as trauma, congenital absence, or natural exfoliation in primary teeth. The simplified oral hygiene index (OHI-S) assessment proposed by Greene and Vermillion was implemented. The simplified oral hygiene index (OHI-S) comprises the Debris Index (DI-S, dental plaque) and the Calculus Index (CI-S, mineralized debris). This index was examined at the lingual faces of the lower first molars, the buccal faces of the upper first molars, and the labial faces of the upper right and lower left incisors. The DI-S and CI-S scores are the two components of the index. They are combined and divided by the number of surfaces. Each individual's index score was determined and rated on a numerical scale from 0 to 3. The nominal scoring scale for assessing the OHI-S was as follows: Good: 0.0–1.2; fair: 1.3–3.0; and poor: 3.1–6.0 [28].

The DMFT/dmft and OHI-S data of the CI recipients and the control group were documented on forms. The oral examinations of all the children were performed by a dentist (Prof. Dr. G. Kılınç).

Ethics committee approval

This analytical cross-sectional clinical study was approved by the Ethics Committee of the Dokuz Eylül University (protocol number: 2021/31 – 13). Written informed consent forms were obtained from the parents of all the children who agreed to participate in the study. This study is in accordance with the ethical standards of the 1964 Declaration of Helsinki and its subsequent revisions.

Data analysis

The Statistical Package for the Social Sciences statistics 29.0.0.0 software (IBM, SPSS Inc., USA) and OpenEpi Program were used for the statistical analysis. The Kolmogorov–Smirnov test of normality was employed to determine if the data distribution was normal. We employed nonparametric tests since our data were not normally distributed ($p < 0.05$). Percentages were used to summarize and compare categorical variables using the Pearson's chi-square test. Statistical analyses of the differences in the oral hygiene index between the groups were performed using the Mann–Whitney U test. Numerical

Table 2 Demographic characteristics of the CI and NH groups

		CI ($n=40$) Mean ± SD	NH ($n=44$) Mean ± SD	*p* values
Chronological age (year)		9.73 ± 2.0	9.72 ± 1.8	$p=0.814$
Gender	**Girl**	25	22	$p=0.249$
	Boy	15	22	
Gestational age (week)	**26–32**	5	6	$p=0.878$
	33–40	35	38	
Number of children in the family (n)		2.18 ± 0.68 (1–4)	2.18 ± 0.62 (1–4)	$p=0.862$
Socioeconomic status (n)	**Lower**	11	7	$p=0.382$
	Middle	22	26	
	Upper	7	11	

*CI: cochlear implanted, NH: normal hearing, n number of subjects, SD: standard deviation, min: minimum, max: maximum, *p < 0.05*

Table 3 Audiological profiles of the cochlear implantation groups

Manufacturer of implants (*n*)	**Nucleus**	25
	MED-EL	11
	Advanced Bionics	4
Implanted Ear (n)	**Right**	24
	Left	12
	Bilateral	4
Age at diagnosis of hearing loss (year, Mean ± SD)		1.03 ± 1.81
Age at cochlear implantation (year Mean ± SD)		2.58 ± 1.76 (min–max: 1–5)
Age at the beginning of rehabilitation (year, Mean ± SD)		1.63 ± 1.03
Duration of implant use (year, Mean ± SD)		7.10 ± 2.49
Language Development Period	**Prelingual (n)**	26
	Perilingual (n)	14
Duration of attendance in special education (year, Mean ± SD)		6.34 ± 2.25
Difficulty listening to the lesson (VAS, Mean ± SD)		1.85 ± 0.95 (min–max: 0–4)
FFA_1(dB, Mean ± SD)		23.93 ± 5.51 (min–max:12–35)
FFA_2(dB, Mean ± SD)		24.13 ± 5.41 (min–max:13–35)
FFA_3(dB, Mean ± SD)		24.22 ± 5.30 (min–max:13–35)
Speech Reception Threshold (dB)		23.37 ± 4.44 (min–max: 15–30)

N: number of subjects, SD: standard deviation, FFA_1: Means of implanted free-field audiometry thresholds at 0.5, 1, 2 kHz frequencies, FFA_2: Means of implanted free-field audiometry thresholds at 1, 2, 4 kHz frequencies, FFA_3: Means of implanted free-field audiometry thresholds at 0.5, 1, 2, 4 kHz, frequencies, min: minimum, max: maximum, dB: decibel, VAS: visual analog scale (0–10)

data are expressed as the mean ± SD, and categorical data are expressed as percentages (%). In all analyses, the value of $p<0.05$ was considered significant.

A sample size calculation was conducted to determine the required number of participants. Based on an expected 10% difference between the groups, a 95% confidence interval, 5% type I error rate, and 80% power, the necessary sample size was determined to be 17 participants per group. Taking into account a 20% attrition rate, the sample size for each group was rounded up to 20 participants. The final study sample consisted of 40 children in the CI group and 44 children in the NH group.

Results

Sample profiles

The CI group consisted of 40 participants (25 females, 15 males) with a mean age of 9.73 ± 2.0 years, and the NH group consisted of 44 children (22 females, 22 males) with a mean age of 9.72 ± 1.8 years. There was no statistically significant difference between the two groups in terms of sex, age, number of children in the family, gestational age at birth, or socioeconomic status ($p>0.05$, Table 2).

The children in the CI group were implanted in the pre/perilingual period. The mean implant age of the children was 2.58 ± 1.76 years. The mean free field test thresholds for FFA_1, FFA_2, and FFA_3 of the implant group were less than 25 dB. Information concerning the audiological profile of the CI group is presented in Table 3.

Sociodemographic characteristics and oral health behaviors of the children

Compared to the NH group, the maternal education levels were significantly lower in the CI group ($p<0.001$, OR = 11.80). When oral health behavior was evaluated, it was determined that the age at which they started

Table 4 Oral hygiene status of the CI and NH groups

		CI (n = 40)	*NH (n = 44)*	*p* values
D/d		*5.18 ± 3.62*	*2.50 ± 1.89*	***0.000****
M/m		*0,05 ± 0.32*	*0.25 ± 0.89*	*0.120*
F/f		*0.25 ± 0.84*	*0.56 ± 1.16*	*0.055*
DMFT/dmft Score		*5.48 ± 3.69*	*3.31 ± 2.57*	***0.006****
DI-S		*2.99 ± 1.15*	*2.04 ± 0.74*	***0.000****
CI-S		*0.79 ± 0.94*	*0.33 ± 0.32*	*0.062*
OHI-S		*3.86 ± 1.95*	*2.38 ± 0.87*	***0.001****
OHI-S Scale (n)	***Poor***	*22*	*6*	***0.000****
	Fair	*16*	*33*	
	Good	*2*	*5*	

*CI: cochlear implanted group, NH: normal hearing group, D/d: decay, M/m: missing, F/f: filling, DMFT/dmft: total index of DMF/dmf, DI-S: Debris Index, CI-S: Calculus Index, OHI-S: Simplified Oral Hygiene Index, *p < 0.05*

brushing their teeth was later (OR = 2.92), and both the frequency of tooth brushing (OR = 5.91) and dental visits (OR = 12.47) were lower in the CI group ($p < 0.05$). Although sugary food consumption did not significantly differ between the groups, the majority of the children in both groups consumed at least one (CI Group: 22, NH Group: 21) or more (CI Group: 22, NH Group: 21) sugary food per day (Table 1).

An inverse, weak and statistically significant correlation was observed between maternal educational status and DMFT/dmft value, D, DI-S, and OHI-S index (rho=-0.31, $p = 0.004$; rho=-0.33, $p = 0.002$; rho=-0.26, $p = 0.015$; rho=-0.26, $p = 0.017$; rho=-0.23, $p = 0.038$, respectively). In our study, there was a correlation between the starting age, frequency of tooth brushing and the educational status of the mothers. As the mothers' education levels increased, the children started brushing their teeth at an earlier age (rho=-0.33 $p = 0.002$) and brushed their teeth more frequently (rho=-0.35 $p = 0.001$). In addition, a significant difference was observed between maternal education levels and the duration of tooth brushing ($p = 0.001$), tooth brushing frequency ($p = 0.012$) and dental examination ($p = 0.042$). A statistically significant correlation was observed between the time of tooth brushing initiation and oral hygiene status (DMFT/dmft value, D, M, CI-S, OHI-S) ($p < 0.05$).

The oral health status, including the DMFT/dmft value, debris, calculus, and oral hygiene index, was significantly different between the CI and NH groups ($p < 0.05$) (Table 4).

When comparing the oral health behavior of children who underwent cochlear implantation during the prelingual and perilingual periods, no significant differences were observed in DMFT/dmft, D/d, M/m, F/f, DI-S, CI-S, or OHI-S values ($p > 0.05$).

Discussion

Oral hygiene is essential for the general health and development of children [29]. There are many factors affecting the general health and quality of life of individuals both with normal hearing and hearing impairment. Oral and dental health are among these important factors. Research has demonstrated that the oral and dental health of hearing-impaired children is worse than that of children with normal hearing [10, 11, 14, 29–33].

This study included 40 children aged between 6 and 13 years with hearing impairment. In our study, the DMFT/dmft, D/d, DI-S, and OHI-S of the CI group were significantly worse than those of the NH group. The parental education levels, tooth brushing status, and frequency of dental visits were significantly different between the two groups. This study revealed that the oral and dental health of cochlear implant users is lower than that of their normal-hearing peers. In our study, we suggest that the oral hygiene and dental health of children with CIs were significantly lower, which may be related to factors such as parental education levels, tooth brushing habits, and frequency of dental visits.

In a systematic review and meta-analysis, Bhadauria et al. evaluated the oral hygiene status of hearing-impaired individuals and reported that these individuals had moderate oral hygiene and the presence of dental plaque and gingivitis [2].

Jeddi Z et al. (2014) stated that regular implant use in an auditory rehabilitation program enables hearing-impaired children to perform similarly to their normal-hearing peers [34]. Cochlear implantation in hearing-impaired individuals not only supports language acquisition but also enhances academic and psychosocial development [20, 35].

Although the available information on the oral hygiene status of the deaf population is limited, to the best of our knowledge, there is no research on children with CI.

In the hypothesis of the study, it was expected that there would be no differences in terms of oral and dental health in children who used regular CI, exhibited language development similar to that of their peers, and attended an auditory rehabilitation program. However, the oral hygiene index and DMFT/dmft index were significantly lower. When we investigated which parameter caused this difference, we observed a significant association between maternal education levels and the dental health and oral hygiene index ($p < 0.05$). To the best of our knowledge, no previous studies have specifically investigated the impact of maternal education on oral and dental health in children with cochlear implants. Therefore, our findings were interpreted in the context of studies conducted on children with hearing impairment and the general pediatric population, where maternal education

has been consistently linked to oral hygiene habits and dental health outcomes.

Swain et al. (2018) noted that oral and dental health are important for children and adults, but it is more critical for hearing-impaired children. They emphasized that health promotion programs and parental education are essential for optimum oral hygiene in these children [10]. Similarly, many researchers have demonstrated the importance of parental education, especially maternal education, in dental health and oral hygiene of hearing-impaired children [8, 32, 33, 36]. In our study, there was a correlation between the starting age and frequency of tooth brushing and the educational status of the mothers.

Mohebbi SZ et al. (2008) reported that mothers are important role models in terms of oral and dental health in early childhood (1–3 years) [37]. In their study of hearing-impaired individuals, Li J et al. (2023) similarly stated that parental education was important for oral hygiene [19]. Even for individuals without hearing loss, studies have indicated that maternal education status is important for oral and dental health [36, 38–40]. Our study revealed that the mother's education is an important factor for better overall oral and dental health. Buldur and Güvendi (2020) stated that in addition to the mother's education levels, the socioeconomic status of the family played a crucial role in children's oral health [8]. Similarly, a study by Campos et al. showed that the socioeconomic status of families of children with hearing-speech disabilities was low, and this factor may negatively affect access to dental health services due to financial difficulties [18]. Consistent with these studies, our findings indicate that maternal education levels are significantly associated with oral hygiene and the dental health outcomes in children with CIs.

In research evaluating the oral hygiene of hearing-impaired children, Wei et al. (2012) used the DMF index to demonstrate a relationship between frequent sugary food consumption and oral health [33]. Although our study did not detect a relationship between the frequency of sugar consumption and oral health, it is noteworthy that most of the children in both groups consumed sugary foods at least once a day.

Another finding was that when compared to the NH group, the CI group had significantly fewer dentist visits. Dentist visits are not limited to only dental examinations; during the examination dentists provide the patients with valuable information concerning oral and dental care. Dental examinations are critical in terms of oral dental health, follow-ups, and control [41]. In individuals with profound hearing loss, the rehabilitation process from diagnosis to implant fitting and beyond has its own costs and challenges. Diagnosis, therapy processes, clinical follow-ups, spare parts, consumables, education, health, and travel costs are some of these costs [42]. This finding also suggested that the strong focus of families on meeting the needs related to hearing loss may be a reason for not making regular dental visits.

Li et al. reported a relationship between daily tooth brushing frequency in children and oral dental health [19]. Moradi G et al. (2019) reported that oral health-related behavioral habits (e.g., tooth brushing frequency, mouth rinsing) are associated with parents' education levels [40]. Kuter et al. (2020) also found a relationship between the frequency of tooth brushing and mothers' education levels [43].

In our study, a significant difference was observed between the time of tooth brushing initiation and the oral hygiene index of the groups ($p < 0.05$), but the high confidence interval of the relationship between the groups may be due to the low number of participants. Therefore, using a larger sample size in the study could not only improve the reliability of the results but also enable their generalization.

Our findings emphasize the importance of parental education and maintaining regular dental check-ups to improve oral and dental health in children with CI. Maternal education levels were found to affect children's oral and dental health. Parents with higher levels of education are believed to have access to more accurate information and resources which subsequently enable them to improve their children's oral hygiene habits, which in turn yields more effective management of their children's oral and dental health. Our study emphasizes that oral and dental health, an important factor affecting the general health and quality of life of hearing-impaired individuals, is an important issue that should be taken into consideration, especially for cochlear implant users. It is important to note that the relationship between maternal education and oral health practices may be bidirectional. Higher maternal education levels can influence access to resources and health literacy, which in turn can positively affect children's oral hygiene habits. On the other hand, the improved oral health of children may also contribute to increased health awareness and literacy in the family, creating a cycle of improvement. Future studies with longitudinal designs would help clarify these causal relationships and their impact on oral health over time. Children with CIs regularly visit otolaryngology and audiology clinics for follow-ups. During these follow-ups, ENT physicians or audiologists may recommend that patients undergo dental check-ups to better maintain their oral hygiene and dental health.

Limitations of the Study.

Our study had some limitations. One of our limitations is that although individuals with CIs and NH were evaluated, a comparison with hearing-impaired individuals as a third group would have allowed more generalizations regarding hearing loss. In our country, hearing loss is

diagnosed at an early stage with national newborn hearing screening, which has been implemented since 2004; and cochlear implantation can be performed for severe to profound hearing loss with state support. As hearing rehabilitation is provided with state support for children with hearing-speech disabilities, the number of referrals to our clinic for these children remains relatively low.

In addition, the number of participants with CIs was lower than expected. However, the study was planned and began to be implemented during the COVID-19 pandemic. It was thought that both families' fear of bringing their children to the hospital as well as the limited age range of patients resulted in the small number of patients. A larger sample would have increased the possibility of generalizing the results.

Moreover, the study did not address the geographic and cultural factors that may influence dental health behaviors and access to care, which could limit the broader applicability of the findings. Another limitation is that the cross-sectional design did not allow for tracking changes in oral health over time. A longitudinal approach could provide deeper insights into both the evolving impact of cochlear implants and maternal education levels on oral hygiene. Future studies with longitudinal designs would be valuable in assessing long-term trends and causality in oral health outcomes among cochlear implant recipients.

Despite these limitations, the results of this study provide valuable information concerning the oral hygiene and dental health of cochlear implant recipients and the effects of maternal educational status.

Conclusion

This study demonstrates a significant association between the oral and dental health of children with cochlear implants (CIs) and their mothers' education levels. Children of more highly educated mothers tended to have better oral hygiene and dental health, which may be linked to greater awareness and adherence to preventive dental care practices. Additionally, compared to their peers, children with CIs exhibited differences in oral health-related behaviors, including toothbrushing frequency and dental visit patterns.

These findings highlight the importance of addressing not only hearing loss but also addressing parental education and oral health awareness when designing interventions for children with CIs.

Integrating oral health education into early intervention and auditory rehabilitation programs may help improve dental care habits in this population. Raising awareness among parents and caregivers may help improve both preventive dental behaviors and overall oral health outcomes.

Further research with larger and more diverse samples is needed to confirm these findings and explore additional social determinants influencing oral health in children with hearing impairment.

Abbreviations

CI	Cochlear implanted group
NH	Normal hearing group
D/d	Decay
M/m	Missing
F/f	Filling
DMFT/dmft	Total index of DMF/dmf
DI-S	Debris Index
CI-S	Calculus Index
OHI-S	Simplified Oral Hygiene Index
dB	decibel
kHz	kiloHertz
Hz	Hertz
FFA1	Means of implanted free-field audiometry thresholds at 0.5, 1, 2 kHz frequencies
FFA2	Means of implanted free-field audiometry thresholds at 1, 2, 4 kHz frequencies
FFA3	Means of implanted free-field audiometry thresholds at 0.5, 1, 2, 4 kHz frequencies

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Author contributions
Concept (SMD, GKilinc, EAG, HEE, YO, GK) and design (SMD, GK, GKilinc, HEE, EAG, YO) of study, acquisition of data (SMD, GKilinc, GK, EAG, HEE, YO), analysis (SMD, GKilinc) and interpretation of data (SMD, GKilinc, HEE, GK, EAG, YO), Drafting the article or revising it critically for important intellectual content (SMD, GKilinc, GK, HEE, EAG, YO). Final approval of the version to be published content (SMD, GKilinc, HEE, EAG, YO, GK). All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the manuscript. The requirements for authorship as stated earlier in this document have been met, and that each author believes that the manuscript represents honest work.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Competing interests
The authors declare no competing interests.

Ethical approval and consent to participate
This analytical cross-sectional clinical research was approved by Dokuz Eylul University, Ethical Committee (protocol number: 2021/31 – 13). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Written informed consent was obtained from all individual participants included in the study.

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