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Original Article

The Association Between Tooth Loss and Hearing Impairment: Partial Compensation with Dental Implants

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BACKGROUND: Some studies have described a relationship between hearing loss and the number of teeth. However, a connection between treatment for tooth loss and hearing improvement remains uncertain. This study aimed to evaluate the association between hearing loss and the number of natural teeth, as well as the association between hearing improvement and dental implants

METHODS: Relevant subjects were retrieved from participants in the 8th Korea National Health and Nutrition Examination Survey conducted between 2020 and 2021. Individuals with available information on demographic factors, underlying diseases, audiological results, and the number of natural teeth and dental implants were included in the analysis. Subjects were categorized into normal hearing, mild hearing loss, and moderate hearing loss groups based on the hearing level of the worse ear.

RESULTS: The normal hearing group had the highest number of natural teeth and dental implants, followed by the mild hearing loss group, and then the moderate hearing loss group ($P < .001$ after adjusting for other factors). Additionally, a linear decrease in hearing level was observed in correlation with the number of natural teeth ($P < .001$) and dental implants ($P < .001$).

CONCLUSION: Hearing loss was significantly associated with tooth loss, and the number of dental implants showed a relationship with lower hearing threshold. Since most sensorineural hearing loss is not curable, and rehabilitation is important, identifying aggravated hearing status in cases of significant tooth loss may be helpful for managing hearing loss.

KEYWORDS: Dental implant, hearing loss, hearing preservation, tooth loss

INTRODUCTION

Hearing loss is the most prevalent sensory disorder, and about half of the general population experiences hearing loss by the age of 80.[1] Some cases of conductive hearing loss can be improved by surgical procedures.[2] However, sensorineural hearing loss is not curable after the acute phase, and rehabilitation with hearing aids is the only available treatment.[2] Additionally, hearing loss tends to progress with age and can cause many functional deficits such as physical inactivity, a higher risk of falling, nutrient insufficiency, depression, loss of social relationships, and cognitive impairment.[2-5] Therefore, controlling the risk factors for hearing loss, detecting it early, and providing appropriate interventions are crucial for preventing deficits caused by hearing loss.

Diabetes is a well-known risk factor for hearing loss. Individuals with diabetes have a 2-fold higher prevalence of hearing loss, and a healthy lifestyle is important for preventing the progression of hearing loss.[6] Loud noise is also an important risk factor for hearing loss.[7] Therefore, wearing ear plugs, avoiding loud noise, and restricting noise exposure time are important for preventing hearing loss.[2,7] Ototoxic chemicals and drugs can cause hearing loss, and reducing exposure to them is crucial for preventing hearing loss.[2] Renal disease is also a risk factor for hearing loss.[8]

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Temporo-mandibular and dental disease and biting are also associated with hearing loss.[9,10] Costen[11] showed that temporo-mandibular joint problems are significantly associated with hearing loss and inner-ear disease,[9,10] while Lawrence et al[12] have demonstrated that hearing loss is inversely related to the number of natural teeth, and loss of natural teeth can result in more severe hearing loss 20 years later. However, these studies did not examine the effects of treatments for tooth loss and biting problems.

The aim of the study was to evaluate the association between tooth loss and hearing impairment using a national population health database. The study was also extended to examine the potential role of dental implants in preventing the progression of hearing loss.

METHODS

Subjects and Inclusion Criteria

Subjects were retrieved among the participants of the 8th Korea National Health and Nutrition Examination Survey (KNHANES) conducted from 2020 to 2021. Korea National Health and Nutrition Examination Survey was annually performed by The Korea Disease Control and Prevention Agency for the general population of South Korea. Korea National Health and Nutrition Examination Survey selects its samples from the general population of the Republic of Korea using a 2-stage stratified sampling method. Among the participants of the 8th KNHANES, individuals with information on age, gender, household income, hypertension, diabetes, history of otitis media, stress (Likert scale, 1-4), daily food intake, occupational noise exposure, as well as results of air-conduction pure tone audiometry, tympanometry, natural-tooth count, and number of dental implants were included.

Hearing Assessment

In the KNHANES, hearing levels are only evaluated in individuals over 40 due to the progressive nature of hearing loss after the age of 40, combined with time and cost constraints. Hearing levels are evaluated with an AD629 audiometer (Interacoustics, Assens, Denmark), which adheres to the current International Organization for Standardization protocol[13] at 0.5 kHz, 1 kHz, 2 kHz, 4 kHz, and 8 kHz in a double-walled soundproof booth. Tympanometry is performed with a Titan IMP440 screener (Interacoustics, Assens, Denmark).

MAIN POINTS

- This study aimed to evaluate the association between hearing loss and the number of natural teeth, as well as the association between hearing improvement and dental implants
- From the public health evaluation database, individuals with information on audiological results, along with the number of natural teeth and dental implants, were included.
- Hearing loss is significantly associated with tooth loss, and higher numbers of dental implants are significantly related to lower hearing thresholds.
- A linear decrease in hearing level was observed in correlation with the number of natural teeth ($P < .001$) and dental implants ($P < .001$).
- Identifying aggravated hearing status in cases of significant tooth loss may be helpful for managing hearing loss.

Mean hearing levels were calculated by averaging hearing levels at 0.5 kHz, 1 kHz, 2 kHz, and 4 kHz. Tympanometry was used to exclude conductive hearing loss in this study.

GROUPING

We classified individuals into 3 categories based on the severity of hearing loss[14]: a normal hearing group consisting of individuals with a mean hearing level of <25 dB in the worse ear; a mild hearing loss group, comprising those with mean hearing levels of >25 dB in the worse ear; and a moderate hearing loss group, consisting of individuals with mean hearing levels of >40 dB in the worse ear.

Survey of Dental Health in Korea National Health and Nutrition Examination Survey

Dental examinations, including the counting of natural teeth and dental implants, were performed by a public health dentist. The total number of natural teeth was 32 in general population, including third molars. Numbers of natural teeth were binned at 8-unit intervals, yielding 4 bins (first bin: 25-32, second bin: 17-24, third bin: 9-16, fourth bin: 0-8) (Table 1).

Numbers of dental implants ranged from 0 to 24, with 97% of subjects having <8 dental implants. Therefore, binning was performed for the number of dental implants using 2-unit intervals, resulting in 4 bins for dental implant counts: a number of dental implants equal to or greater than 6 was included in the first bin (first bin: 6-24, second bin: 4-5, third bin: 2-3, fourth bin: 0-1) (Table 1).

Ethics

This study was conducted in accordance with STROBE guidelines. Also, the 8th KNHANES was performed with approval from the Institutional Review Board (IRB) of Korea Disease Control Agency (IRB nos. 2018-01-03-2C-A: approved on June 30, 2020, and 2018-01-03-5C-A: approved on March 31, 2021). All participants gave informed consent before they participated in the 8th KNHANES.

Statistical Analysis

Analysis of variance and chi-square tests were performed to compare numbers of natural teeth and dental implants between groups, and analysis of covariance was used to compare variables between groups while adjusting for covariates. Linear regression analysis was performed to examine the association between mean hearing levels of bilateral ears and numbers of natural teeth or dental implants. Univariable analyses are presented as mean ± standard error, as are adjusted values. SPSS version 25.0 (IBM Corp., Armonk, NY, USA) was used for all statistical analyses. Symbols *, **, and *** in the figures represent *P*-values less than .05, .01, and .001, respectively.

RESULTS

Subjects Included

Of the 9026 participants aged 40 or older, 4861 were included for whom there was information on age, gender, income, hypertension, diabetes, history of otitis media, stress, daily food intake, occupational noise exposure, hearing level, tympanic membrane status, and the number of natural teeth and dental implants. Of these, 4436 subjects with normal tympanic membranes were finally included in our study (Figure 1).

Table 1. Demographics of the Study Population

Variable	Values	Variable	Values
Age (years)	59.86 ± 11.69	Number of natural teeth (mean ± SD)	23.25 ± 7.83
Gender (M : F)	1886 : 2550	First bin (25-32) (cases)	3019
House hold income (quintile)	3.10 ± 1.39	Second bin (17-24) (cases)	752
Fifth (cases)	948	Third bin (9-16) (cases)	278
Fourth (cases)	953	Fourth bin (0-8) (cases)	387
Third (cases)	887		
Second (cases)	903		
First (cases)	745		
Hypertension (%)	34.02	Number of dental implant (mean ± SD)	1.09 ± 2.26
Diabetes (%)	15.24	First bin (6-24) (cases)	249
History of otitis media	3.04%	Second bin (4-5) (cases)	242
Stress (4-point Likert scale, 1: extremely, 4 rarely)	2.92 ± 0.73	Third bin (2-3) (cases)	543
Daily food intake (g)	1456.80 ± 729.42	Fourth bin (0-1) (cases)	3402
Occupational noise exposure	16.97%		
Hearing threshold (dB)	22.14 ± 14.31		
Hearing group			
Normal (cases)	2707		
Mild hearing loss (cases)	1016		
Moderate HL (cases)	713		

F, female; HL, hearing loss; M, male; SD, standard deviation.

Demographic Factors, Underlying Disease, Stress, Food Intake, and Occupational Noise Exposure History

The mean age of the subjects was 59.86 ± 11.69; there were 1866 males and 2550 females. Mean household income was 3.10 ± 1.39 (quintile), and 34.02% and 15.24% of the subjects, respectively, suffered from hypertension and diabetes. Among the subjects, 3.04% had a history of otitis media, with a mean stress level of 2.92 ± 0.73 and a daily food intake of 1456.80 ± 729.42 g. Additionally, 16.97% of the subjects had a history of occupational noise exposure (Table 1).

Numbers of Natural Teeth and Dental Implants in the Hearing Groups

The numbers of individuals assigned to the normal hearing group, mild hearing loss group, and moderate hearing loss group were

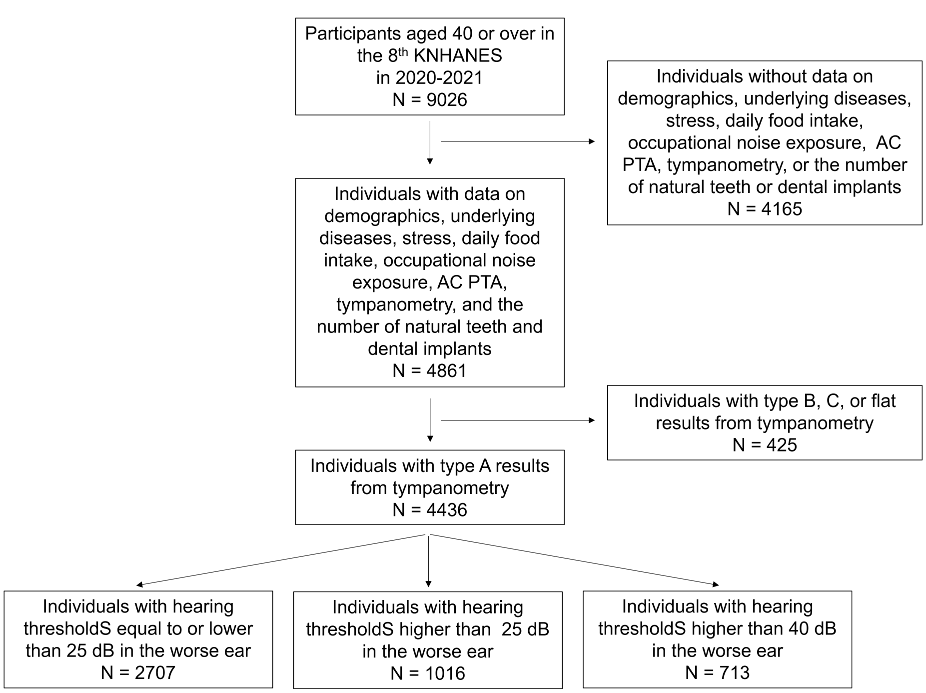

Figure 1. Flowchart of inclusion of study subjects from database. AC, air-conduction; KNHANES, Korea National Health and Nutrition Examination Survey; n, number; PTA, pure tone audiometry.

Table 2. Comparison of Demographic Parameters According to Hearing-Loss Group

Variable	Group			Total (5712)	*P*
	Normal Hearing (n = 2707)	Mild HL (n = 1016)	Moderate HL (n = 713)		
Age (years)	54.70 ± 9.81	65.60 ± 9.55	71.25 ± 8.76	59.86 ± 11.69	<**.001**
Gender (M : F)	969 : 1739	525 : 491	393 : 320	1886 : 2550	<**.001**
Household income (quintile)	3.45 ± 1	2.75 ± 1.36	2.30 ± 1.30	3.10 ± 1.39	<**.001**
Fifth (%)	27.45	13.88	8.98	16.79	
Fourth (%)	25.27	18.31	11.64	20.36	
Third (%)	21.35	19.69	15.29	20.00	
Second (%)	16.48	24.90	28.61	21.48	
First (%)	9.46	23.23	35.48	21.37	
Hypertension (%)	24.90	45.87	51.75	34.02	<**.001**
Diabetes (%)	10.12	20.77	26.79	15.24	<**.001**
History of OM (%)	3.03	3.64	5.05	3.49	**.032**
Stress (1-4, 1: extremely, 4 rarely)	2.84 ± 0.72	3.01 ± 0.73	3.10 ± 0.75	2.92 ± 0.73	<**.001**
Daily food intake (g)	1532.24 ± 724.16	1401.82 ± 773.76	1248.72 ± 631.10	1456.80 ± 729.42	<**.001**
Occupational noise exposure (%)	13.85	22.83	20.48	16.97	<**.001**

The statistically significant *P*-value was depicted in bold.
F, female; HL, hearing loss; M, male; n, number; OM, otitis media.

2707, 1016, and 713, respectively. The hearing groups differed significantly in age ($P < .001$), gender ($P < .001$), household income ($P < .001$), prevalence of hypertension ($P < .001$) and diabetes ($P < .001$), history of otitis media ($P = .032$), stress ($P < .001$), daily food intake ($P < .001$), and occupational noise exposure ($P < .001$) (Table 2).

They also differed in numbers of natural teeth (normal hearing: 25.51 ± 5.60, mild hearing loss: 21.27 ± 8.57, moderate hearing loss: 17.48 ± 9.98, $P < .001$) in univariable analysis; they also differed in the number of dental implants (normal hearing: 1.13 ± 0.04, mild hearing loss: 1.12 ± 0.07, moderate hearing loss: 0.89 ± 0.08, $P = .036$) in an analysis adjusted for the number of natural teeth.

In the multivariable analysis concerned with the number of natural teeth, adjustments were made for age, gender, household income, hypertension, diabetes, history of otitis media, stress, daily food intake, occupational noise exposure, and the same variables, along with the number of natural teeth, were considered in the case of dental implants. The number of natural teeth and dental implants were significantly different between the groups ($P < .001$ for each for natural teeth and dental implants).

In the post-hoc test, the normal hearing group had the highest number of natural teeth (23.83 ± 0.14, $P = .021$ compared with the mild hearing loss group, and $P < .001$ compared with moderate hearing loss group), followed by the mild hearing loss group (23.11 ± 0.22, $P < .001$ compared with moderate hearing loss group), while the moderate hearing loss group had the lowest number of natural teeth (21.24 ± 0.28) (Figure 2A).

Additionally, the moderate hearing loss group had a lower number of dental implants (0.76 ± 0.09) than the normal hearing group (1.19 ± 0.05, $P < .001$) and the mild hearing loss group (1.04 ± 0.07, $P = .028$) (Figure 2B).

Hearing Levels According to Numbers of Natural Teeth and Dental Implants

The mean hearing levels of the 8-unit number bins of natural teeth were compared. The hearing levels differed significantly and decreased with increasing number of natural teeth ($P < .001$) (Table 3). This effect was maintained after adjusting for age, gender, household income, hypertension, diabetes, history of otitis media, stress, daily food intake, and occupational noise exposure ($P < .001$) (Figure 3A).

The mean hearing levels between the 2-unit number bins of dental implants were also compared after adjusting number of natural teeth. The hearing level in the 2-unit number bins was significantly different ($P < .001$) (Table 3). After adjusting age, gender, household income, hypertension, diabetes, history of otitis media, stress, daily food intake, occupational noise exposure, and the number of natural teeth, hearing levels appeared to decrease with the number of dental implants ($P = .017$) (Figure 3B).

Table 3. Crude Analysis of Hearing Levels According to Numbers of Natural Teeth and Dental Implants

Natural Teeth	Hearing Level (dB)[a]	Dental Implants	Hearing Level (dB)[b]
First bin	18.28 ± 12.34	First bin	19.68 ± 0.85
Second bin	26.89 ± 14.01	Second bin	24.09 ± 0.83
Third bin	31.22 ± 13.83	Third bin	24.19 ± 0.55
Fourth bin	36.45 ± 14.79	Fourth bin	21.85 ± 0.22
P	<**.001**	*P*	<**.001**

The statistically significant *P*-value was depicted in bold.
[a]Univariable analysis, expressed as mean ± standard deviation.
[b]Results for the number of natural teeth-adjusted values, expressed as mean ± standard error.

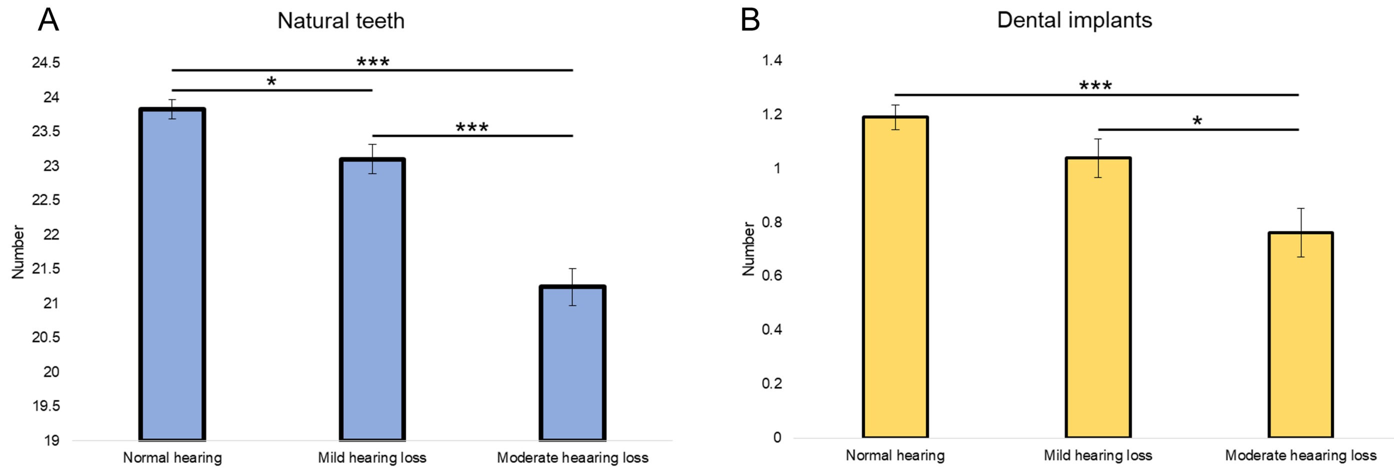

Figure 2. Comparison of numbers of natural teeth (A) and dental implants (B) between hearing groups (multivariable analysis). *Statistically significant difference between the bins; *$P < .05$; **$P < .01$; ***$P < .001$.

Linear Associations of Hearing Level with Number of Natural Teeth and Number of Dental Implants

After adjusting age, gender, household income, hypertension, diabetes, history of otitis media, stress, daily food intake, and occupational noise exposure, the number of natural teeth ($\beta=-0.113$, $P < .001$) and number of dental implants ($\beta=-0.036$, $P=.002$) were significantly associated with mean hearing level (Table 4). Age ($\beta=0.531$, $P < .001$), gender ($\beta=-0.166$, $P < .001$), household income ($\beta=-0.078$, $P < .001$), diabetes ($\beta=0.039$, $P=.008$), history of otitis media ($\beta=0.064$, $P < .001$), stress ($\beta=0.024$, $P < .030$), daily food intake ($\beta=-0.054$, $P < .001$), and occupational noise exposure ($\beta=0.073$, $P < .001$) also displayed significant relationships with mean hearing level (Table 4).

DISCUSSION

It has been shown that hearing level is significantly associated with the number of natural teeth, and also with the number of dental implants after adjusting number of teeth and demographic factors. Additionally, the numbers of natural teeth and dental implants were significantly lower in patients with moderate hearing loss.

Previous studies have also concluded that dental health is significantly related to hearing impairment. Costen[11] demonstrated that hearing loss was significantly associated with temporomandibular joint problems,[9,10,15] and suggested that this association was the result of middle ear change and of central nervous system plasticity caused by temporomandibular joint problems.[9-11,15] Also, several groups have also reported that hearing loss is significantly related to the number of teeth, and that individuals who have lost many teeth have a higher prevalence of hearing loss.[12,16,17] Poor oral hygiene was much more prevalent in individuals with hearing impairments.[18] Additionally, 1 study found a significant association between poor oral hygiene and sudden sensorineural hearing loss.[19] Furthermore, the present study identified a relationship between dental implants and hearing loss, as well as between hearing loss and the number of natural teeth, while accounting for comprehensive demographic and underlying factors. Since both the number of teeth and hearing ability are crucial in maintaining the quality of life in geriatrics,[20,21] providing dental care to patients with hearing loss, or evaluating hearing loss in patients with severe tooth loss, should also be considered.

The findings of the study also highlight the connection between dental health and hearing loss through their impact on food intake. This aligns with previous research, which has shown that poor dental health can lead to inadequate food and nutrient intake.[4] Although this study demonstrates that the number of dental implants and natural teeth are related, even after adjusting for food intake, specific nutrients were not considered. What is critical for maintaining health is not merely the amount of food consumed but the balanced intake

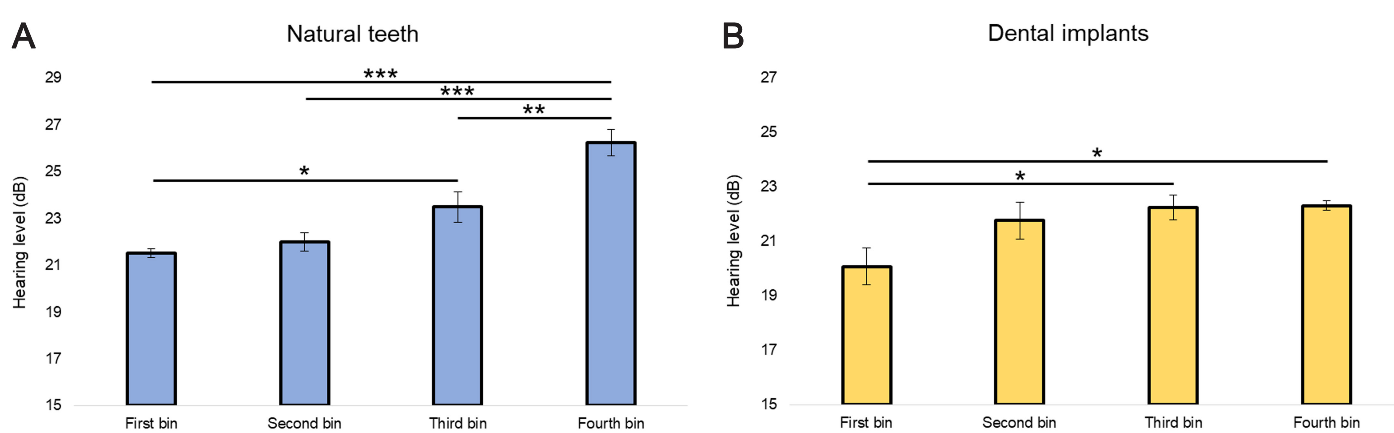

Figure 3. Relation between hearing level and (A) number of natural teeth and (B) number of dental implants (multivariable analysis). *Statistically significant difference between the bins; *$P < .05$; **$P < .01$; ***$P < .001$.

Table 4. Linear Regression Analysis of Hearing Levels

Variable	B (95% CI)	SE	*β*	*t*	*P*
Age (years)	0.651 (0.616 to 0.686)	0.018	0.531	36.456	**<.001**
Gender (female)	−4.798 (−5.443 to −4.152)	0.329	−0.166	−14.569	**<.001**
Household income (quintile)	−0.805 (−1.057 to −0.554)	0.128	−0.078	−6.275	**<.001**
Hypertension (%)	0.131 (−0.581 to 0.844)	0.364	0.004	0.361	.718
Diabetes (%)	1.572 (0.684-2.460)	0.453	0.039	3.470	**.001**
History of OM (%)	5.026 (3.369-6.683)	0.845	0.064	5.946	**<.001**
Stress (1-4, 1: extremely, 4 rarely)	0.472 (0.045-0.898)	0.218	0.024	2.167	**.030**
Daily food intake (g)	−0.001 (−0.002 to −0.001)	0.0002	−0.054	−4.646	**<.001**
Occupational noise exposure	2.771 (1.951-3.591)	0.418	0.073	6.626	**<.001**
Number of natural teeth	−0.206 (−0.254 to −0.158)	0.024	−0.113	−8.406	**<.001**
Number of dental implants	−0.225 (−0.368 to −0.082)	0.073	−0.036	−3.092	**.002**

The statistically significant *P*-value was depicted in bold.
F, female; M, male; OM, otitis media.

of essential nutrients, including various vitamins, minerals, fatty acids, and proteins.[22] However, these aspects were not adequately considered. Patients with poor oral health often struggle to achieve a balanced nutrient intake.[23] Given that poor nutrition is associated with hearing loss and may even contribute to its development, the observed associations between hearing loss and the number of natural teeth or dental implants may be influenced by nutritional status.[4,24]

Further investigation that considers each nutrient individually in the analysis of the relationship between hearing loss and dental health may provide valuable insights into the role of each nutrient as a potential covariate.

Another potential explanation is that hearing loss and the loss of natural teeth share a common etiology, such as demineralization of the temporal bone and cochlea.[12] This hypothesis suggests that the association between hearing loss and a lower number of dental implants may stem from inadequate bone thickness and subsequent demineralization of the mandibular bone.[12] When the remaining bone is very thin, placing dental implants becomes more challenging, potentially resulting in fewer implants.[25] Furthermore, hearing loss and tooth loss may both be influenced by common vascular conditions and comorbidities, including diabetes.[26,27] Although these hypotheses are plausible, direct evidence supporting them remains limited. Further research is required to elucidate the mechanisms underlying the relationship between dental health and hearing loss.

Some studies have proposed that tooth loss may contribute to degenerative changes in the central nervous system, potentially leading to hearing impairment.[17] Tooth loss is associated with degenerative changes in the brain and in cognitive function,[28,29] and since hearing loss can be caused by such changes, it could be an indirect consequence of dentition loss.[17] Based on this hypothesis, dental implants may be associated with lower hearing thresholds in tooth loss patients, as found in the study, because they are associated with less cognitive decline.[30,31]

In addition, changes in mastication can induce alterations in auditory function by affecting noise-canceling pathways and somatic stimulation. Masticatory noise level is about 55 dB,[32] and changes in masticatory noise can induce alterations in noise-canceling pathways in the temporal auditory cortex, prefrontal cortex, and somatosensory cortex, leading to sensory gating.[33-36] The alterations in the auditory cortex may affect auditory function.[33] Additionally, somatic stimulation of the masticatory nerve can modulate neurological pathways converging in the dorsal cochlear nucleus, potentially leading to auditory problems.[37] The modulation of noise-canceling pathways and somatic stimulation resulting from tooth loss could be partially compensated for by dental implants, which would restore both masticatory noise and somatic sensation, leading to lower hearing thresholds in individuals with more implants. Further studies are needed to elucidate the exact neural pathways associated with tooth-loss-related hearing defects.

The main limitation of the study was the difficulty in establishing causality due to its cross-sectional design, which inherently restricts the determination of causal relationships. Considering the study design was cross-sectional, the observed association should not be interpreted as a causal relationship. Furthermore, data on certain demographic and socio-economic factors, such as access to medical care and living conditions, were not available. Although the study adjusted for variables like nutrition, occupational noise exposure, and stress levels to account for socio-economic influences, other potential confounding factors were not included in the analysis. Given that dental health and tooth loss, as well as the number of implants, were significantly associated with socio-economic status,[38,39] potential confounders should be considered in future studies. In addition, detailed audiological information, such as bone-conduction thresholds or speech audiometry results, was not available. Although tympanometry was used to exclude abnormalities of the tympanic membrane, the absence of bone-conduction data limited the ability to differentiate between sensorineural, mixed, and conductive hearing loss. Additionally, the possibility of selection bias might be present in this study, as non-responders to the survey were not represented in the KNHANES database, and individuals with missing data were excluded. Furthermore, the study was conducted within a single ethnic group, which restricts the generalizability of the findings to other populations. Future research incorporating a prospective design, multi-ethnic validation, and more comprehensive demographic and audiological evaluations would provide a more precise understanding of these associations.

CONCLUSION

Hearing loss is significantly associated with tooth loss, and higher numbers of dental implants are significantly related to lower hearing thresholds. Given that most cases of sensorineural hearing loss are incurable and require rehabilitation, recognizing aggravated hearing status in individuals with significant tooth loss could aid in the management of hearing impairment. Furthermore, in patients with hearing loss, identifying severe natural tooth loss and recommending dental implants may contribute to improving their overall quality of life.

Availability of Data and Materials: The data used in this study can be accessed at https://knhanes.kdca.go.kr/knhanes/main.do#.

Ethics Committee Approval: The 8th Korea National Health and Nutrition Examination Survey was conducted with approval from the Institutional Review Board (IRB) of the Korea Disease Control and Prevention Agency (IRB nos. 2018-01-03-2C-A, approved on June 30, 2020, and 2018-01-03-5C-A, approved on March 31, 2021).

Informed Consent: Written informed consent was obtained from the patients/patient who agreed to take part in the survey.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – S.Y.H., J.H.C.; Design– S.Y.H., J.H.C.; Supervision – S.H.L., J.H.C.; Resources – S.H.L., J.H.C.; Materials – S.Y.H., H.W.S.; Data Collection and/or Processing – S.Y.H., H.W.S.; Analysis and/or Interpretation – S.Y.H., J.H.C.; Literature Search – S.Y.H., H.W.S., S.H.L., J.H.C.; Writing – S.Y.H.; Critical Review – J.H.C.

Declaration of Interests: The authors have no conflicts of interest to declare.

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