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Combined Effect of Toothbrushing and Interdental Cleaning on the Risk of Dementia

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Purpose: Systemic inflammation contributes to dementia risk by promoting amyloid beta production and enhancing brain neurotoxicity. While oral hygiene is key in managing inflammation, few studies have assessed the combined effect of toothbrushing frequency and interdental cleaning on dementia risk. This study examined the association between oral hygiene behaviors and dementia onset among older Korean adults.

Materials and Methods: A retrospective cohort study followed participants for 11 years using data from the National Health Insurance Service–National Health Information Database. Kaplan–Meier estimates computed cumulative incidence probabilities, and differences between oral hygiene groups were evaluated using the log-rank test. Cox proportional hazards models were applied to evaluate the impact of oral hygiene behaviors on dementia incidence, estimating the hazard ratio (HR) and 95% confidence interval (CI).

Results: Higher frequency of toothbrushing and interdental cleaning device use were each significantly associated with reduced dementia risk ["≥3 times toothbrushing daily," adjusted HR (aHR)=0.85; "always using interdental cleaning devices," aHR=0.89], though no clear linear dose-response pattern was observed. Combined frequent toothbrushing and interdental cleaning showed a further risk reduction ["≥2 times toothbrushing with interdental cleaning (always or sometimes)," aHR=0.75], regardless of dementia type. Professional dental cleaning within 1 year (aHR=0.88) and always brushing before sleep (aHR=0.82) were also associated with lower risk.

Conclusion: Proper oral hygiene practices, especially toothbrushing combined with interdental cleaning, were associated with a lower risk of dementia.

Key Words: Cognition disorders, dementia, epidemiologic studies, oral hygiene, retrospective studies

INTRODUCTION

Dementia continues to attract societal attention due to its prolonged duration of prevalence.[1] Dementia is a progressive and irreversible condition that causes difficulties in daily activities by affecting cognitive abilities and behaviors.[2] South Korean society has already become a super-aged society, and the number of older adult individuals with dementia is continuously increasing. In 2023, the annual care cost per dementia patient was approximately 26.4 million KRW, accounting for 43.8% of the annual household income of 60.3 million KRW.[3] Additionally, national dementia care costs were reported at 22.9 trillion KRW, representing approximately 0.95% of the gross domestic

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product.[3] A serious concern is that this financial burden could rise steadily in the future.

The pathophysiology of dementia involves the accumulation of amyloid beta (Aβ) peptides and tau proteins in the brain, disrupting neuronal function.[4] Notably, the aggregation of Aβ plaques is associated with extensive neurodegeneration, leading to gradual neuronal atrophy and memory loss.[5] Numerous studies have observed that periodontal diseases can affect systemic inflammatory responses, potentially contributing to neurodegeneration.[6-12] Specifically, acute-phase reactants [e.g., serum amyloid A protein, C-reactive protein (CRP)] and pro-inflammatory cytokines [e.g., interleukin (IL)-1, IL-6, and tumor necrosis factor-α] can enhance brain neurotoxicity by promoting Aβ production and aggregation.[5,13] A previous case-control study reported a statistically significant impact of systemic inflammation markers (e.g., high-sensitivity CRP and IL-6) on the relationship between periodontitis and both Aβ1-40 and Aβ1-42 peptides in their mediation analysis.[10] Taken together, these findings suggest that improving modifiable oral health-related lifestyle factors may reduce systemic inflammation, which plays a role in cognitive impairment.

In 2017, the WHO emphasized the need to confirm the correlation between dementia and modifiable lifestyle-related factors, such as physical activity, eating habits, and cognitive stimulation, while also identifying dementia risk factors through population based-research.[2] Oral hygiene management is considered a crucial element in minimizing local and systemic inflammation. Mature dental plaque promotes the growth of Gram-negative anaerobic bacteria, which produce endotoxins. This process initiates and sustains chronic inflammation, resulting in irreversible damage to periodontal tissues.[14] Personal oral hygiene practices are modifiable behaviors that individuals can actively adopt to prevent oral diseases.[15,16] Despite its importance, few studies have specifically assessed the combined effect of toothbrushing frequency and interdental cleaning on dementia risk, and even fewer have accounted for dementia subtype differences. This study aimed to evaluate whether proper oral hygiene practices can reduce the risk of dementia among older Korean adults.

MATERIALS AND METHODS

Data sources and study population

This retrospective longitudinal cohort analysis is based on the National Health Insurance Service–National Health Information Database (NHIS–NHID) data. The dataset merged customized claims data with dental and medical diagnostic records and health screening data. The NHIS is a compulsory insurance system in South Korea, requiring all citizens and registered residents to enroll. The NHIS claim data can be utilized to establish a cohort for follow-up monitoring based on the diagnostic code record. The definition of diseases was based on diagnostic codes categorized by the Korean Standard Classification of Diseases-8. Enrolled citizens of the NHIS undergo a biennial health examination program, which consists of medical and dental health check-ups. The dental health check-up includes an oral health survey and a comprehensive examination performed by professional dentists, involving visual, dental, and oral soft-tissue examinations. The oral health survey is a self-reported questionnaire that addresses dental history, oral health awareness, and behaviors affecting oral health.

Dementia typically manifests after age 65, but pathological changes can begin years earlier.[2] Thus, we included adults aged 50 years and older who participated in a health examination program, including a dental check-up, in 2009 or 2010 (Fig. 1), to ensure adequate follow-up into the high-risk age range during the observation period. Exclusion criteria were as follows: 1) death within 2 years from baseline (n=9563); 2) diagnosed with dementia within 2 years of baseline (n=18006); 3) presence of complete edentulism (n=22343); 4) missing values for sex and age (n=2609); and 5) missing values for confounding factors (n=22007). During the follow-up period, participants were classified into two groups according to the incidence of dementia.

Ethics and approvals

This study was approved by the Institutional Review Board of Kyungpook National University (approval no. 2023-0386). The requirement for written informed consent was waived because

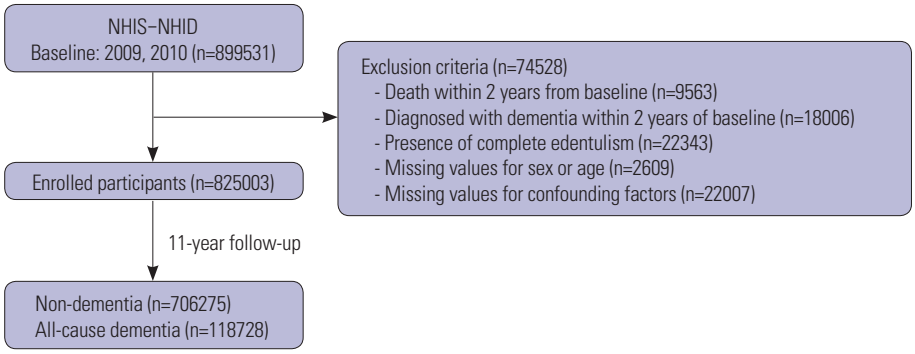

Fig. 1. Flowchart of the process for selecting eligible participants. Follow-up period for subjects identified in 2009: January 2011–December 2021; follow-up period for participants identified in 2010: January 2012–December 2022. NHIS–NHID, National Health Insurance Service–National Health Information Database.

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the analysis used anonymous and de-identified data. The reporting was conducted in full accordance with the World Medical Association's Declaration of Helsinki.

Exposure: oral hygiene behaviors

Oral hygiene behaviors were assessed using baseline oral health survey data. The assessment included toothbrushing frequency (0–1, 2, or ≥3 times/day), the use of interdental cleaning devices (e.g., dental floss and/or interdental brushes), professional dental cleaning visits (≤1 year or >1 year), and the practice of toothbrushing before sleep. The use of interdental cleaning devices and the practice of toothbrushing before sleep were recategorized into "never," "sometimes," and "always." Subsequently, toothbrushing frequency (0–1 or ≥2 times/day) and the use of interdental cleaning devices ("never" or "always or sometimes") were combined to assess their joint effect on dementia risk, given that interdental cleaning devices are typically used as a supplement to toothbrushing rather than alone. To isolate the effect of not brushing before sleep, individuals who reported brushing 0 times per day (n=2937) were excluded.

Outcome: dementia

Confirmed or newly diagnosed dementia was identified after a 2-year wash-out period from the baseline to exclude individuals with pre-existing dementia or suspected cognitive impairment at enrollment. We selected a 2-year duration with reference to previous claims-based studies,[7,9] as longer wash-out periods may increase the likelihood of misclassification due to reduced specificity.[17] Incident dementia cases were defined as those assigned one or more of the following diagnostic codes: F00 [dementia in Alzheimer's disease (AD)], F01 [vascular dementia (VaD)], F02 (dementia in other diseases classified elsewhere), F03 (unspecified dementia), G30 (AD), and G31 (other degenerative diseases of the nervous system, not elsewhere classified). Participants were followed for up to 11 years from baseline until the onset of dementia, all-cause mortality, or the end of the follow-up period. Since participants who died during follow-up could no longer develop dementia, all-cause mortality was treated as a censoring event. Subgroup analyses classified dementia cases into AD (F00 or G30), VaD (F01), and other specified dementia (F02, F03, or G31; OD).

Covariates

Demographic and socioeconomic information, such as sex, age, type of residence area, and income level, was obtained from the qualification and insurance premium database. Diagnoses of comorbidities, such as diabetes mellitus (E10–14), cardiovascular diseases (I20–25) and cerebrovascular accidents (I60–64), were gathered from the NHIS claim data. Anthropometric measurements, laboratory findings, and health behaviors were obtained from data collected in the health screening programs. Hypertension was defined according to the guidelines of the Korean Society of Hypertension as a systolic blood pressure of ≥140 mm Hg and/or a diastolic blood pressure of ≥90 mm Hg. Dyslipidemia was defined according to the guidelines of the Korean Society of Lipid and Atherosclerosis, with classification made if one or more of the following criteria were met: total cholesterol ≥240 mg/dL, low-density lipoprotein cholesterol ≥160 mg/dL, high-density lipoprotein cholesterol <40 mg/dL, or triglycerides ≥200 mg/dL. Information about the participants' health behaviors, including smoking status, alcohol consumption, and frequency of moderate physical activity, was obtained from the self-reported questionnaire. Dental caries was identified by clinical detection of crown or root caries and/or by diagnostic or treatment codes. Periodontal diseases were identified by clinical detection of periodontal inflammation and/or by diagnostic or treatment codes. Since baseline data on the number of missing teeth were unavailable, partial edentulism was defined as the absence of complete edentulism. Specific details are presented in Supplementary Table 1 (only online).

Statistical analysis

Survival analysis was performed to examine the correlation between oral hygiene behaviors and incident dementia over an 11-year period. Pearson chi-square tests, Student's t-tests, and one-way analysis of variance tests were conducted to compare general characteristics between the groups. Kaplan–Meier estimates were used to compute cumulative incidence probabilities, and a log-rank test assessed statistical significance between the groups. Cox proportional hazards regression model was used to estimate hazard ratios (HRs) and 95% confidence intervals (CIs). These models were adjusted for confounding factors such as demographic characteristics, socioeconomic status, comorbidities, and health behaviors. The incidence rate per 1000 person-years was calculated by considering censored data (i.e., right-censored due to death or event occurrence). We performed sensitivity analyses without adjusting for dental caries and periodontal disease, which may affect oral hygiene behaviors. The results are shown in Supplementary Table 2 (only online). Simultaneously, age-stratified subgroup analyses were performed for the dementia subtypes AD, VaD, and OD.

Statistical analyses were conducted using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA) and R version 4.0.3 (The R Foundation for Statistical Computing, Vienna, Austria). Two-sided statistical tests were used, with statistical significance set at $p<0.05$.

RESULTS

Baseline characteristics of the study participants

Based on the inclusion criteria, 74528 participants were excluded, while the remaining 825003 participants were monitored (Fig. 1). Incident all-cause dementia was identified in 118728 participants (14.4%) over an average follow-up period of 9.6

years (Table 1). Notably, a substantial proportion of the participants were aged under 65 years (61.3%). More than half of the participants resided in urban areas and belonged to the highest income quintile (i.e., fifth quintile). The most prevalent comorbidities among the participants were dyslipidemia (35.5%), periodontal diseases (34.0%), and partial edentulism (30.1%). Supplementary Tables 3 to 7 (only online) show that proper oral hygiene practices, such as "≥2 times toothbrushing daily+using interdental cleaning devices (always or sometimes)," "dental visits for professional dental cleaning (≤1 year)," and "toothbrushing before sleep (always)," were generally associated with the lowest prevalence of comorbidities. Moreover, both the group with "0–1 times toothbrushing daily" and the group with "using interdental cleaning devices (always)" showed a higher proportion of participants who frequently consumed alcohol and were current or former smokers.

Comparison of the survival curves according to oral hygiene behaviors

As shown in Fig. 2 and Supplementary Fig. 1 (only online), participants with infrequent toothbrushing and no use of interdental cleaning devices exhibited a significantly higher cumulative incidence of all-cause dementia than those with consistent oral hygiene practices (p<0.001). However, the group that "0–1 times toothbrushing daily+using interdental cleaning devices (always or sometimes)" had lower cumulative incidence of dementia compared to the group that "≥2 times toothbrushing daily+never using interdental cleaning devices."

Association between oral hygiene behaviors and incident dementia

Results from the Cox proportional hazards analysis indicated that proper oral hygiene practices were significantly associated with a lower risk of all-cause dementia. Specifically, a higher frequency of toothbrushing (≥3 times daily) and consistent interdental cleaning (always) were each independently associated with reduced dementia risk, with adjusted HRs (aHRs) of 0.85 (95% CI=0.84–0.87), and 0.89 (95% CI=0.88–0.90), respectively. In addition, professional dental cleaning within the past year (aHR=0.88; 95% CI=0.86–0.89) and always brushing before sleep (aHR=0.82; 95% CI=0.81–0.84) were also significantly associated with a decreased risk of all-cause dementia (Table 2).

Notably, the combined practice of frequent toothbrushing and interdental cleaning (≥2 times daily brushing with always or sometimes using interdental cleaning devices) was associated with the lowest risk of dementia among all oral hygiene behaviors examined (aHR=0.75; 95% CI=0.73–0.76) (Table 2).

Subgroup analyses

Subgroup analyses showed that the associations between oral hygiene behaviors and dementia risk were consistent across dementia subtypes. For the AD group, "≥2 times toothbrushing daily+using interdental cleaning devices (always or sometimes)," "dental visits for professional dental cleaning (≤1 year)," and "toothbrushing before sleep (always)" showed adjusted HRs of 0.71 (95% CI=0.69–0.73), 0.84 (95% CI=0.82–0.86), and 0.79 (95% CI=0.77–0.81). Similarly, the VaD group showed adjusted HRs of 0.74 (95% CI=0.65–0.83), 0.87 (95% CI=0.81–0.94), and 0.86 (95% CI=0.77–0.96). In contrast, the OD group showed no significant association for dental visits for professional dental cleaning (≤1 year) alone (Fig. 3 and Supplementary Tables 8-10, only online). The age-stratified subgroup analyses generally showed consistent associations across all groups, except for the ≥75 years groups of VaD and OD (Supplementary Tables 11–14, only online).

DISCUSSION

This longitudinal study demonstrated that proper oral hygiene behaviors were significantly associated with a reduced risk of incident dementia over an 11-year follow-up period. Specifically, individuals who combined frequent toothbrushing with interdental cleaning exhibited a significantly lower incidence of dementia compared to those who did not. These findings highlight the critical importance of consistent oral self-care in maintaining cognitive health in older adults.

Periodontal disease results from an imbalance in host-microbial interactions, in which dental plaque bacteria contribute to chronic inflammation and tissue damage.[14,18] This damage occurs both directly and indirectly, and the balance can be altered by factors such as reduced host resistance (i.e., innate and adaptive immune responses), increased dental biofilm, or increased bacterial virulence.[19] Although toothbrushing is the most effective mechanical method for removing dental plaque, cleaning the interdental and proximal surfaces requires the use of supplementary devices (e.g., interdental cleaning devices).

Overall, our study results show that toothbrushing daily with the use of interdental cleaning devices is associated with a decreased risk of dementia onset. Specifically, "≥2 times of toothbrushing daily and using interdental cleaning devices (always or sometimes)" was associated with the lowest risk of all-cause dementia, showing a 25% lower risk compared to "0–1 times of toothbrushing daily and never using interdental cleaning devices." A previous longitudinal study found that frequent toothbrushing (≥2 times/day) was associated with decreased periodontal pocket depth.[20] A randomized clinical trial reported that combining toothbrushing with the use of interdental cleaning devices effectively reduced dental plaque and gingival inflammation in individuals with periodontitis.[15] Additionally, a cross-sectional study reported that regular oral hygiene management (i.e., flossing and using mouthwash twice daily) may lead to an increased presence of beneficial bacterial genera within Proteobacteria, while reducing the abundance of known oral pathogens, including *Saccharibacteria*, *Bacteroides*, and *Pepto-*

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Table 1. Characteristics of Study Participants

	Total (n=825003)	Non-dementia (n=706275, 85.6%)	All-cause dementia (n=118728, 14.4%)	*p*
Sex, female	458277 (55.5)	382299 (54.0)	76978 (64.8)	<0.001
Age (yr)				
Average	62.84±7.25	61.84±6.62	68.83±6.82	<0.001
≤64	505315 (61.3)	474189 (67.1)	31126 (26.2)	<0.001
65–74	268979 (32.6)	203621 (28.8)	6358 (55.0)	
≥75	50709 (6.1)	28465 (4.0)	22244 (18.7)	
Type of residence area (urban)	441597 (53.5)	384935 (54.5)	56662 (47.7)	<0.001
Income level				<0.001
Covered by medical aid	2637 (0.3)	1790 (0.3)	847 (0.7)	
1 quintile (lowest)	131149 (16.3)	112539 (16.4)	18590 (16.1)	
2 quintile	108300 (13.5)	94660 (13.8)	13640 (11.8)	
3 quintile	129524 (16.1)	112253 (16.3)	17271 (14.9)	
4 quintile	172903 (21.5)	147985 (21.5)	24918 (21.6)	
5 quintile (highest)	258438 (32.2)	218119 (31.7)	40319 (34.9)	
Body mass index (kg/m^2)				<0.001
Normal (18.5–24.9)	470877 (57.5)	402446 (57.4)	68431 (58.1)	
Underweight (≤18.4)	14210 (1.7)	11399 (1.6)	2811 (2.4)	
Overweight (25.0–29.9)	299340 (36.6)	257606 (36.8)	41734 (35.4)	
Obesity (≥30.0)	34287 (4.2)	29498 (4.2)	4789 (4.1)	
Systolic blood pressure (mm Hg)	126.99±15.4	126.75±15.30	128.46±15.91	<0.001
Diastolic blood pressure (mm Hg)	77.36±9.85	77.43±9.98	76.95±9.98	<0.001
Total cholesterol (mg/dL)	201.69±108.49	201.72±107.48	201.55±114.31	0.629
High-density lipoprotein cholesterol (mg/dL)	56.07±44.87	56.07±44.88	56.11±44.79	0.780
Low-density lipoprotein cholesterol (mg/dL)	116.65±88.31	116.63±87.02	116.77±95.61	0.633
Triglyceride (mg/dL)	146.32±135.54	146.60±137.02	144.70±126.32	<0.001
Smoking status (current or former)	252191 (31.0)	225195 (32.3)	26996 (23.1)	<0.001
Alcohol consumption (per week)				<0.001
None	559385 (69.2)	467890 (67.6)	91495 (78.7)	
1 time	98262 (12.2)	88797 (12.8)	9465 (8.1)	
2 or more times	150542 (18.6)	135252 (19.5)	15290 (13.2)	
Moderate physical activity (per week)				<0.001
None	479821 (59.3)	400855 (57.8)	78966 (67.7)	
1–2 times	140745 (17.4)	125916 (18.2)	14829 (12.7)	
3 or more times	189048 (23.4)	166258 (24.0)	22795 (19.6)	
Comorbidities				
Hypertension	171592 (21.0)	143464 (20.5)	28128 (23.9)	<0.001
Diabetes mellitus	229885 (27.9)	194390 (27.5)	35495 (29.9)	<0.001
Cardiovascular diseases	85122 (10.3)	72048 (10.2)	13074 (11.0)	<0.001
Cerebrovascular accidents	47735 (5.8)	37317 (5.3)	10418 (8.8)	<0.001
Dyslipidemia	290711 (35.5)	248597 (35.5)	42114 (35.8)	0.055
Partial edentulism	248220 (30.1)	199969 (28.3)	48251 (40.6)	<0.001
Dental caries	165687 (22.5)	140668 (22.7)	25019 (21.5)	<0.001
Periodontal diseases	265491 (34.0)	226462 (33.9)	39029 (34.8)	<0.001
Frequency of toothbrushing				<0.001
0–1 times	81863 (9.9)	66315 (9.4)	15548 (13.1)	
2 times	404666 (49.1)	346163 (49.0)	58503 (49.3)	
≥3 times	338474 (41.0)	293797 (41.6)	44677 (37.6)	
Use of interdental cleaning devices				<0.001
Never	508560 (61.6)	425626 (60.3)	82934 (69.9)	

Table 1. Characteristics of Study Participants (continued)

	Total (n=825003)	Non-dementia (n=706275, 85.6%)	All-cause dementia (n=118728, 14.4%)	*p*
Sometimes	77597 (9.4)	68850 (9.7)	8747 (7.4)	
Always	238846 (29.0)	211799 (30.0)	27047 (22.8)	
The frequency of toothbrushing and the use of interdental cleaning devices				
0–1 times+Never	60452 (7.3)	47807 (6.8)	12645 (10.7)	
0–1 times+Always or sometimes	21411 (2.6)	18508 (2.6)	2903 (2.4)	
≥2 times+Never	448108 (54.3)	377819 (53.5)	70289 (59.2)	
≥2 times+Always or sometimes	295032 (35.8)	262141 (37.1)	32891 (27.7)	
Dental visits for professional dental cleaning (≤1 year)	237966 (28.8)	212449 (30.1)	25517 (21.5)	<0.001
Practice of toothbrushing before sleep				<0.001
Never	73446 (8.9)	59253 (8.4)	14193 (12.0)	
Sometimes	369801 (45.0)	315078 (44.8)	54723 (46.3)	
Always	378819 (46.1)	329649 (46.8)	49170 (41.6)	

All values are presented as n (%) for categorical variables or as mean±SD for continuous variables. For the practice of toothbrushing before sleep, participants who reported never brushing their teeth were excluded (n=2937). The data were analyzed using Pearson's chi-square test and Student's t-test (p<0.05).

streptococcaceae.[21] Periodontal diseases may affect systemic inflammatory responses, potentially contributing to neurodegeneration.[6-12] These findings suggest that the pathogenic factors and metabolites released by these harmful bacteria may be involved in the onset of dementia. Considering that dementia progresses slowly over 5 to 20 years, consistent optimal oral hygiene behaviors from an early age are crucial for potentially reducing the risk of dementia.

Many studies have shown a relationship between the development of dementia and various diseases, including non-communicable diseases (NCDs).[22-24] Additionally, there is growing evidence supporting professional dental cleaning in reducing the risk of NCDs.[25-27] Thus, professional dental cleaning is an effective management strategy for NCDs, which are considered a common risk factor for dementia. Our study shows that regular professional dental cleaning has a significant preventive effect against dementia. These results are consistent with those reported in a recent study, which found that regular professional dental cleaning is associated with a reduced incidence of dementia in adults (adjusted odds ratio=0.92).[28] However, the subgroup with OD was not statistically significant (p>0.05). Dementia has diverse pathogenic mechanisms, and OD (e.g., Lewy body dementia, frontotemporal dementia, Creutzfeldt-Jakob disease, and Huntington's disease) is known to have stronger genetic factors.[29-31] This can be considered as a reason for the relatively lower preventive effects observed among OD. Although the OD group did not show significant associations, regular professional dental cleaning remains a potentially important preventive strategy, given that AD and VaD account for the majority of dementia cases.

Toothbrushing before sleep showed a significant association with a reduced risk of incident dementia across all subtypes. Indeed, dry mouth significantly contributes to the increase in oral microorganisms. Dry mouth is an aspect of oral frailty common among older adults. The reduction in salivary flow leads to compromised oral cleansing and increased susceptibility to dental caries and periodontal diseases.[32] For older adults, dry mouth may be exacerbated by polypharmacy associated with comorbidities.[33] Consequently, toothbrushing before sleep is especially critical in this population. Also, the tendency for individuals who practice toothbrushing before sleep is to have better overall oral hygiene behaviors,[34] suggesting a potentially greater preventive effect.

AD is characterized by Aβ plaques and tau neurofibrillary tangles,[4] whereas VaD is primarily associated with cerebral atherosclerosis, arteriosclerosis, small vessel disease, and cerebral amyloid angiopathy.[35] Mixed dementia (AD with VaD) is common in older adults, indicating an overlap between neurodegenerative and vascular pathologies.[36] In our study, subgroup analyses were limited to individuals diagnosed exclusively with either AD or VaD during follow-up. Nevertheless, no significant differences were observed in the effects of oral hygiene behaviors across the dementia subtypes. A recent meta-analysis investigating systemic inflammation markers reported that elevated levels of CRP are associated with an increased long-term risk of VaD.[37] Chronic systemic inflammation contributes to neuroinflammation and VaD by increasing blood-brain barrier permeability,[38] promoting microthrombus formation, and activating endothelial inflammation. Excess reactive oxygen species induced by periodontitis may activate NADPH oxidase pathways,[39] similar to those involved in other neuroinflammatory risk factors.[40] These mechanisms suggest that periodontal inflammation may contribute to dementia risk via oxidative stress and neurovascular dysfunction. Thus, managing periodontal inflammation may serve as an effective strategy for individuals at high risk of VaD, particularly those with prior ischemic stroke.

The strengths of this study are as follows. First, to the best of our knowledge, this is the first study to evaluate how the combined practice of toothbrushing and interdental cleaning influences the risk of dementia. Second, the study uses a nation-

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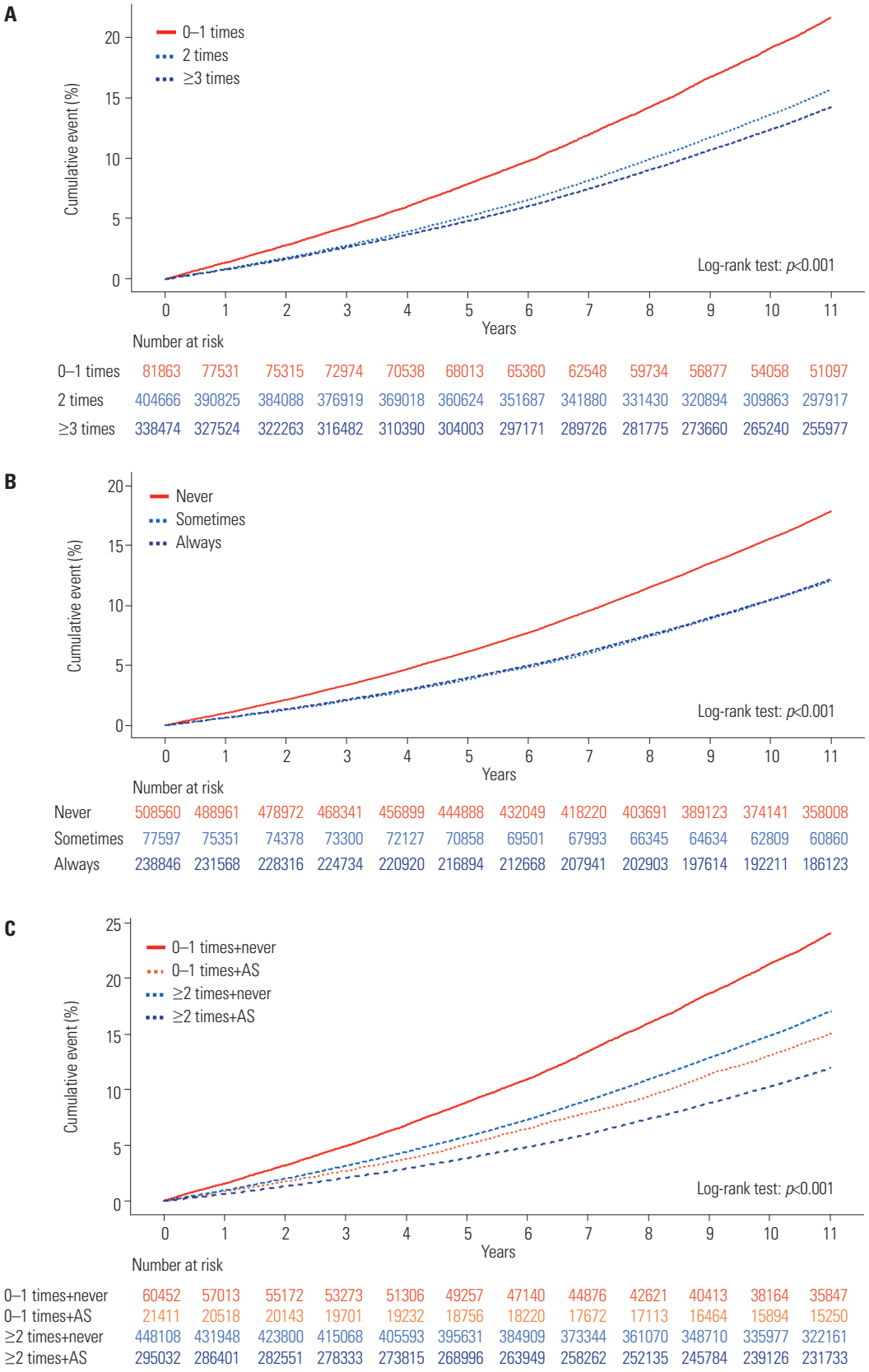

Fig. 2. Cumulative incidence of all-cause dementia based on oral hygiene behaviors. (A) Frequency of toothbrushing. (B) Use of interdental cleaning devices. (C) The frequency of toothbrushing and the use of interdental cleaning devices. The data were analyzed using the log-rank test ($p<0.05$). AS, always or sometimes.

ally representative population-based sample, ensuring high representativeness and broad generalizability of the findings. Third, subgroup analyses confirmed the consistent preventive effects of oral hygiene behaviors across dementia subtypes. Finally, the retrospective cohort design enabled temporal assessment, supporting causal inference between oral hygiene be-

Table 2. HRs for Incident All-Cause Dementia by Oral Hygiene Behaviors Over 11 Years

	Total	All-cause dementia		HR (95% CI) for all-cause dementia			
	n	Event	IR	Crude	*p*	Adjusted*	*p*
Frequency of toothbrushing							
0–1 times	81863	15548	21.36	Reference		Reference	
2 times	404666	58503	15.07	0.70 (0.68–0.71)	<0.001	0.85 (0.83–0.87)	<0.001
≥3 times	338474	44677	13.62	0.63 (0.62–0.64)	<0.001	0.85 (0.84–0.87)	<0.001
Use of interdental cleaning devices							
Never	508560	82934	17.35	Reference		Reference	
Sometimes	77597	8747	11.43	0.65 (0.64–0.67)	<0.001	0.84 (0.82–0.86)	<0.001
Always	238846	27047	11.54	0.66 (0.65–0.67)	<0.001	0.89 (0.88–0.90)	<0.001
The frequency of toothbrushing and the use of interdental cleaning devices							
0–1 times+Never	60452	12645	24.03	Reference		Reference	
0–1 times+Always or sometimes	21411	2903	14.39	0.59 (0.57–0.61)	<0.001	0.85 (0.81–0.89)	<0.001
≥2 times+Never	448108	70289	16.52	0.68 (0.66–0.69)	<0.001	0.85 (0.83–0.86)	<0.001
≥2 times+Always or sometimes	295032	32891	11.31	0.46 (0.45–0.47)	<0.001	0.75 (0.73–0.76)	<0.001
Dental visits for professional dental cleaning							
>1 year	587037	93211	16.88	Reference		Reference	
≤1 year	237966	25517	10.77	0.63 (0.62–0.64)	<0.001	0.88 (0.86–0.89)	<0.001
Practice of toothbrushing before sleep†							
Never	73446	14193	21.54	Reference		Reference	
Sometimes	369801	54723	15.61	0.72 (0.70–0.73)	<0.001	0.92 (0.90–0.94)	<0.001
Always	378819	49170	13.29	0.61 (0.60–0.62)	<0.001	0.82 (0.81–0.84)	<0.001

IR, incidence rate per 1000 person-years; HR, hazard ratio; CI, confidence interval.
Cox proportional hazards regression was performed, with statistical significance set at $p<0.05$.
*Adjusted for sex, age, type of residence area, income level, body mass index, smoking status, alcohol consumption, moderate physical activity, comorbidities (diabetes mellitus, cardiovascular diseases, cerebrovascular accidents, hypertension, dyslipidemia, dental caries, periodontal diseases, and partial edentulism); †Participants who reported never brushing their teeth before sleep were excluded from the analysis (n=2937).

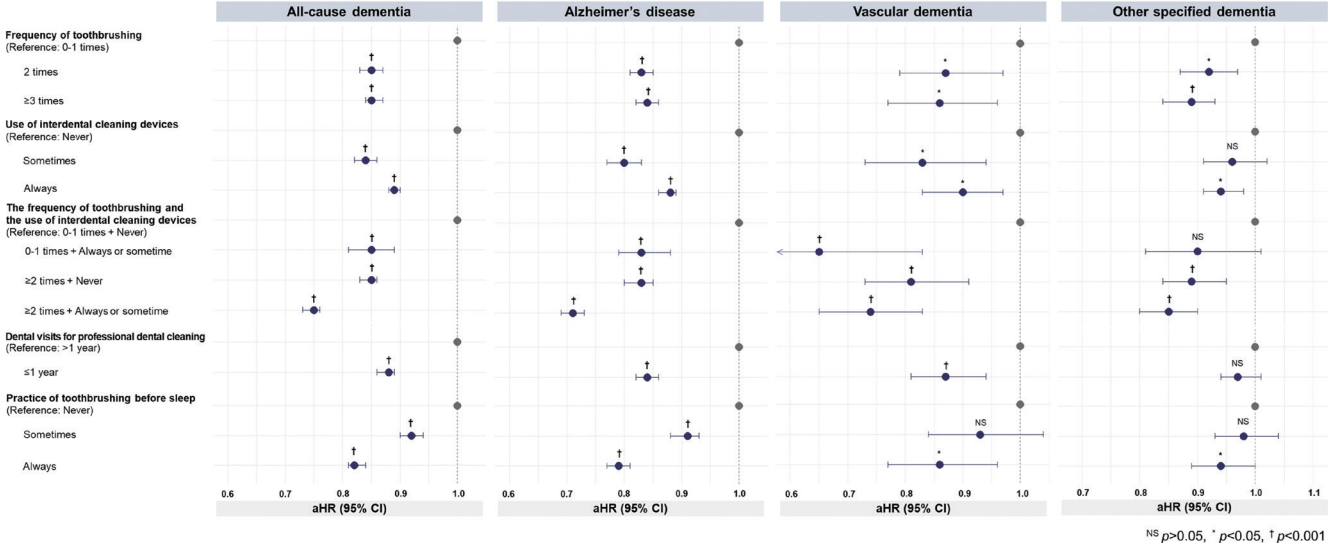

Fig. 3. aHR for incident all-cause dementia by oral hygiene behaviors over 11 years (subgroup analyses by dementia subtypes). The data were analyzed using Cox proportional hazards regression ($p<0.05$). Adjusted for sex, age, type of residence area, income level, body mass index, smoking status, alcohol consumption, moderate physical activity, comorbidities (diabetes mellitus, cardiovascular diseases, cerebrovascular accidents, hypertension, dyslipidemia, and partial edentulism). aHR, adjusted hazard ratio; CI, confidence interval.

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haviors and dementia incidence. However, our study also has several limitations. First, although this study has a nationwide population-based design, it included only individuals who underwent health screening, so inherent selection bias should be considered when interpreting the results. Second, the etiologic diagnosis of dementia was based on the NHIS claim data when a patient visited the hospital and was assigned a principal diagnosis. While the specificity of the data is generally high, the actual time of disease occurrence may differ from the claims date. Third, we applied a 2-year wash-out period to exclude participants with pre-existing dementia, although some undiagnosed or very early-stage cases may remain. Future studies should perform sensitivity analyses to assess the impact of varying this period. Fourth, we calculated HRs and adjusted for confounding factors, but some biases may remain due to omitted variables, such as cognitive function, daily living activities, prescription medications, and the type and number of remaining teeth. Fifth, there is a potential for reverse causation, where early manifestations of preclinical dementia may reflect worsening oral hygiene behaviors rather than serving as a causal risk factor. Finally, oral hygiene behaviors were self-reported, so biases relating to recall error and missing responses are possible.

In conclusion, proper oral hygiene practices, especially toothbrushing combined with interdental cleaning, were associated with a lower risk of dementia. Further research is required to understand the mechanisms and causal pathways linking interdental cleaning and incident dementia, as well as other modifiable oral health-related lifestyle behaviors.

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