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Original Study

Number of Teeth and Dementia-free Life Expectancy: A 10-Year Follow-Up Study from the Japan Gerontological Evaluation Study

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A B S T R A C T

Objectives: Previous studies have reported that tooth loss is associated with an increased risk of dementia; however, few have explored the association between number of teeth and dementia-free and total life expectancies. We investigated whether having more teeth is associated with longer dementia-free and total life expectancies.
Design: A 10-year follow-up prospective cohort study from 2010 to 2020.
Setting and Participants: Functionally independent older adults aged ≥65 years living in 9 municipalities in Japan.
Methods: The exposure was the number of teeth (≥20, 10−19, 1−9, and 0). Dementia onset and mortality within the 10-year follow-up were used as the outcome. Dementia-free and total life expectancies according to the number of teeth were derived from multistate modeling estimates.
Results: A total of 44,083 participants were included (men: 46.8%). The mean age was 73.7 years [standard deviation (SD) = 6.0]. During follow-up, 17.3% and 21.4% of the participants experienced the onset of dementia and death, respectively. Having fewer teeth was associated with dementia [hazard ratio (HR), 1.14; 95% confidence interval (CI), 1.07−1.22, 10−19 teeth; HR, 1.15; 95% CI, 1.08−1.22, 1−9 teeth; HR, 1.13; 95% CI, 1.05−1.21, 0 teeth] and death (HR, 1.13; 95% CI, 1.05−1.22, 10−19 teeth; HR, 1.27; 95% CI, 1.19−1.37, 1−9 teeth; HR, 1.47; 95% CI, 1.36−1.59, 0 teeth) compared with having ≥20 teeth. Dementia-free life expectancies at the age of 65 years were 16.43 years and 18.88 years with ≥20 teeth, and 14.40 years and 17.12 years with 0 teeth for men and women, respectively. The total life expectancies at the age of 65 were 17.84 years and 22.03 years with ≥20 teeth, and 15.42 years and 19.79 years with 0 teeth for men and women, respectively.
Conclusions and Implications: Having more teeth was associated with longer dementia-free and total life expectancies.

The duration for living with a disability is increasing due to aging populations,[1] with dementia being a principal contributor to disability.[2] In 2019, dementia affected approximately 57.4 million individuals, and this figure is projected to rise to 152.8 million cases by 2050, underscoring the urgent need for substantial attention.[3] Concurrently, the duration of living with dementia is expected to increase. Given the overall quality of life throughout an individual's life span, understanding both total life expectancy (LE) and dementia-free LE is essential.

Data were obtained from the Japan Gerontological Evaluation Study (JAGES). All inquiries will be addressed by the Data Management Committee via e-mail: dataadmin.ml@jages.net. All JAGES datasets have ethical or legal restrictions for public deposition owing to the inclusion of sensitive information from human participants.

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Calculating total and dementia-free LEs is critical for building long-term care policies in aging societies. Absolute dementia-free LE, rather than dementia transition rates, is more interpretable by health professionals, caregivers, and policymakers.[4,5] Dementia-free LE can be estimated by calculating transition probabilities derived from a multistate survival model.[6] Previous studies have used multistate modeling and multistate life tables to calculate LE without comorbidities, including dementia.[4,7-9] One study demonstrated that maintaining a healthy lifestyle may increase the proportion of remaining years without Alzheimer's dementia.[7]

Better oral health may contribute to extended dementia-free LE. Several studies have indicated an association between oral health and dementia.[10-13] A systematic review revealed that individuals with tooth loss had a 1.28-fold higher risk of developing dementia.[10] Possible mechanisms for this association include inadequate nutrition,[12,14] fewer social relationships,[12] and decreased brain stimulation.[10,11] The association between the number of teeth and dementia suggests that having more teeth might delay or prevent the onset of dementia, potentially leading to a longer dementia-free LE.[10-13] Two Japanese studies on oral health and disability demonstrated that oral health care and having more teeth were associated with longer disability-free LE.[15,16]

As most oral diseases are preventable, it is important to investigate whether differences in the number of teeth is associated with longer dementia-free and total LEs. Therefore, this study aimed to investigate whether having more teeth is associated with longer dementia-free and total LEs, and calculate age-specific dementia-free and total LEs based on the number of teeth.

Methods

Data and Study Design

This prospective cohort study used data from the Japan Gerontological Evaluation Study (JAGES) over 10 years of follow-up from 2010 (baseline). JAGES is an ongoing cohort study aimed at functionally independent older adults aged ≥65 years to promote a society of healthy longevity. In 2010, a postal survey questionnaire was distributed to 80,744 participants in 9 municipalities who were not certificated for long-term care insurance. Among the 51,923 respondents (response rate: 64.3%), we identified instances of dementia and death by combining the survey respondents with municipal records up to 2020. We excluded participants with an invalid ID, sex, or age (n = 5073); those lost to follow-up (n = 706); and those requiring supportive care for basic daily activities at baseline (n = 2061). Our analytical sample included 44,083 participants. Supplementary Figure 1 shows a flowchart of the study population.

Exposure Variable

The number of teeth was used as the exposure variable. Participants were asked, "How many natural teeth do you have?" and the responses were recorded as ≥20 teeth, 10–19 teeth, 1–9 teeth, and 0 teeth. We used this variable across 4 categories in accordance with a previously published study.[11] According to a prior validation study,[17] the self-reported number of teeth is broadly consistent with clinically examined counts, particularly in older populations.

Outcome Variables

The outcome variables were the onset of dementia and mortality, obtained from the public long-term care insurance system via municipal records.[18] Three transitions were modeled: non-dementia to dementia, non-dementia to death, and dementia to death (Supplementary Figure 2). Dementia onset was determined based on the "Activities of Daily Living Independence Assessment Criteria for Older Individuals with Dementia" scale. Trained investigators conducted home visits to assess the level of care required using a standardized protocol, with the care level determined by the long-term care approval board, together with the opinion of physicians.[19] The scale includes levels I–IV and medical (M) levels; the onset of dementia was determined based on a score of level II or higher on the dementia scale. This cutoff was commonly used in other previous studies from the JAGES cohort study and the Japan Public Health Center–based prospective study.[12,13,19,20] This assessment of dementia correlates with Mini-Mental State Examination scores.[21]

Covariates

Covariates were selected based on previous research and clinical expertise.[10-12] Age (continuous), sex (men, women), education level (<9 years, 10–12 years, ≥13 years), marital status (having partner, no partner), annual equivalent household income (Japanese yen in millions; < 1.00, 1.00–1.99, 2.00–2.99, 3.00–3.99, ≥4.00), walking time (<30 min, 30–59 min, 60–89 min, ≥90 min a day), depression (Geriatric Depression Scale (GDS-15)[22] <5, 5–9, ≥10), drinking history (current, past, never), smoking history (current, past, never), and presence of comorbidities (diabetes, hypertension, stroke, heart diseases) were included. The equivalent household income was calculated by dividing the household income by the square root of the number of household members.

Statistical Analysis

First, we examined the descriptive characteristics of individuals transitioning from non-dementia to dementia, non-dementia to death, and dementia to death during a 10-year follow-up. Second, we applied multistate survival modeling using the Royston-Parmar flexible parametric model. This analysis calculated transition probabilities from non-dementia to dementia (transition 1), non-dementia to death (transition 2), and dementia to death (transition 3) based on the number of teeth category. Hazard ratios (HRs) and 95% CIs were calculated for each transition. Transition probabilities were estimated as each observation progressed until reaching an absorbing state or being censored at the maximum follow-up. LE was estimated using transition probabilities from the models. The analysis was conducted using STATA "*multistate*" and "*stmerlin*" packages.[23-25]

We calculated LE from the crude model for each sex. The adjusted model (model 1) included sex, age, and number of teeth; model 2 included the other covariates, such as education level, annual equivalent household income, walking time, depression, drinking history, smoking history, and presence of comorbidities (diabetes, hypertension, stroke, and heart disease). In addition, we calculated LE with or without dementia, and the total LE over 30 years for each age group (65–89 years) for each sex, based on the number of teeth. The estimates from the multistate models with 10-year follow-up data were extrapolated, assuming that the association would persist for 30 years. To reduce selection bias, we performed random forest imputation using the R package "*missForest*" for missing data.[26]

To ensure the robustness of the results, we conducted a sensitivity analysis excluding those with dementia onset and death within 1 year from baseline. In addition, we conducted the analysis fitting with the Weibull distribution and Gompertz distribution, rather than the Royston-Parmar model. We estimated the LE with and without dementia, as well as the total LE for those with 65 years.

All analyses were performed using STATA 18.0 (Stata Corporation LP, Windows version) and R (version 4.2.3, Windows). The significance level was set at $P < .05$. This study followed the STROBE guidelines for reporting.

Ethical Approval

The JAGES study was approved by the Ethics Committee of the National Center for Geriatrics and Gerontology (approval number: 992), Chiba University (approval number: 2493), and Tohoku University Graduate School of Medicine (21–40).

Results

A total of 44,083 participants (46.8% men) were included in this study. The maximum follow-up period was 3775 days (mean: 2783.4 days for dementia and 3086.8 days for death). The mean age at baseline was 73.7 [standard deviation (SD): 6.0] years. During the follow-up period, 17.3% of participants experienced dementia onset, and 21.4% of these individuals died. Among those who experienced dementia, 43.8% subsequently died. The incidence rates of dementia onset and death were 1.67 per 100 person-years and 2.07 per 100 person-years, respectively. Table 1 and Supplementary Table 1 show the descriptive characteristics of the study population. Individuals with fewer teeth tended to transition from non-dementia to dementia, non-dementia to death, and dementia to death. The distribution of variables remained consistent with those observed before imputation (Supplementary Tables 2 and 3).

The expected total LE for participants aged 65 years, as determined by the crude model, was 20.99 years (dementia-free LE: 19.48 years) for men and 24.73 years (dementia-free LE: 22.38 years) for women (Table 2). These expected total LE closely align with values calculated by the Ministry of Health, Labour and Welfare in Japan in 2010 (18.9 years for men and 23.9 years for women).[27]

Table 1
Descriptive Characteristics of the Analytical Sample at Baseline (n = 44,083)

Baseline Characteristics	Total Participants [N (col%)]	Onset of Dementia (Row%)		Onset of Death (Row%)	
		No (n = 36,478)	Yes (n = 7605)	No (n = 34,654)	Yes (n = 9429)
Number of teeth					
≥20	15,432 (35.0)	88.2	11.8	85.8	14.2
10–19	11,516 (26.1)	84.6	15.4	81.1	18.9
1–9	11,331 (25.7)	79.0	21.0	74.2	25.8
0	5804 (13.2)	71.9	28.1	63.1	36.9
Sex					
Men	20,634 (46.8)	83.8	16.2	71.5	28.5
Women	23,449 (53.2)	81.8	18.2	84.9	15.1
Educational level, y					
<9	20,217 (45.9)	79.8	20.2	75.6	24.4
10–12	15,673 (35.6)	85.0	15.0	81.2	18.8
≥13	8193 (18.6)	85.7	14.3	80.9	19.1
Marital status					
No partner	12,364 (28.0)	75.8	24.2	75.3	24.7
Having partner	31,719 (72.0)	85.4	14.6	79.9	20.1
Income (Japanese million yen)					
<1.00	8110 (18.4)	74.5	25.5	73.9	26.1
1.00–1.99	14,668 (33.3)	83.7	16.3	78.0	22.0
2.00–2.99	9941 (22.6)	84.5	15.5	79.7	20.3
3.00–3.99	6354 (14.4)	86.4	13.6	81.7	18.3
≥4.00	5010 (11.4)	85.2	14.8	81.8	18.2
Walking time, min/d					
<30	14,851 (33.7)	77.0	23.0	71.9	28.1
30–59	15,370 (34.9)	83.8	16.2	80.3	19.7
60–89	6943 (15.7)	86.4	13.6	82.8	17.2
≥90	6919 (15.7)	89.1	10.9	85.2	14.8
Depression (Geriatric Depression Scale)					
<5	32,517 (73.8)	84.4	15.6	80.8	19.2
5–9	8861 (20.1)	78.6	21.4	73.1	26.9
≥10	2705 (6.1)	76.4	23.6	70.4	29.6
Drinking history					
Current	16,166 (36.7)	86.4	13.6	78.5	21.5
Past	1456 (3.3)	79.5	20.5	64.8	35.2
Never	26,461 (60.0)	80.7	19.3	79.4	20.6
Smoking history					
Current	4761 (10.8)	83.3	16.7	70.4	29.6
Past	13,013 (29.5)	83.6	16.4	71.9	28.1
Never	26,309 (59.7)	82.2	17.8	83.4	16.6
Diabetes					
No	38,137 (86.5)	83.0	17.0	79.2	20.8
Yes	5946 (13.5)	80.9	19.1	74.9	25.1
Hypertension					
No	21,723 (49.3)	81.6	18.4	77.1	22.9
Yes	22,360 (50.7)	83.9	16.1	80.1	19.9
Stroke					
No	43,558 (98.8)	82.8	17.2	78.8	21.2
Yes	525 (1.2)	77.9	22.1	65.0	35.0
Heart diseases					
No	38,430 (87.2)	83.4	16.6	80.1	19.9
Yes	5653 (12.8)	78.4	21.6	68.2	31.8
Age, mean (SD)	73.7 (6.0)	72.7 (5.5)	78.4 (6.1)	72.6 (5.3)	77.7 (6.6)
Total	44,083 (100.0)	82.7	17.3	78.6	21.4

Table 2
Expected LE at 65 Years From the Age-Adjusted Model for Each Sex

	At 65 Years Old		
	Dementia-free LE, y	LE With Dementia, y	Total LE, y
Men	19.48	1.52	20.99
Women	22.38	2.35	24.73

The LE was calculated by the age-adjusted model.

Table 3 presents the results for each transition of the multistate models. Compared with those with ≥20 teeth, individuals with fewer teeth were more likely to develop dementia (HR, 1.14; 95% CI, 1.07–1.22 for 10–19 teeth; HR, 1.15, 95% CI, 1.08–1.22 for 1–9 teeth; HR, 1.13, 95% CI, 1.05–1.21 for 0 teeth) and to die (HR, 1.13, 95% CI, 1.05–1.22 for 10–19 teeth; HR, 1.27, 95% CI, 1.19–1.37 for 1–9 teeth; HR, 1.47, 95% CI, 1.36–1.59 for 0 teeth). Among those diagnosed with dementia, fewer teeth were also associated with increased mortality (HR, 1.18, 95% CI, 1.07–1.32 for 10–19 teeth; HR, 1.20, 95% CI, 1.09–1.33 for 1–9 teeth; HR, 1.33, 95% CI, 1.19–1.48 for 0 teeth).

Figure 1 illustrates the expected LE with and without dementia, and the total LE by the number of teeth across ages 65–89 years, using the transition probabilities from multistate modeling shown in Table 3. Table 4 shows the results for participants aged 65 years extracted from Figure 1. Dementia-free LEs at 65 years of age were 16.43 years and 18.88 years for participants with ≥20 teeth, compared with 14.40 years and 17.12 years for those with 0 teeth, for men and women, respectively. The total LEs at 65 years were 17.84 years and 22.03 years for participants with ≥20 teeth, and 15.42 years and 19.79 years for participants with 0 teeth for men and women, respectively. Thus, both dementia-free LE and total LE were longer in individuals with more teeth, and women exhibited greater LE than men. Additionally, LE with dementia was slightly longer among those with more teeth at baseline.

Supplementary Tables 4 and 5 show the results of the sensitivity analysis, which excluded individuals who experienced dementia onset or death within 1 year from baseline. These results show a tendency similar to that of the main analysis. Supplementary Tables 6–9 display results using different distributions, revealing similar trends, although the duration of LE differs depending on the distribution.

Discussion

Summary of the Findings

Our study highlights that having more teeth is associated with longer dementia-free and total LEs. Specifically, dementia-free LEs at 65 years of age were 2.04 years longer for men and 1.75 years longer in women with ≥20 teeth compared with those with 0 teeth. Based on the duration of dementia, the LEs of participants at 65 years of age with ≥20 teeth had an increase of 0.39 years for men and 0.49 years for women compared with those with 0 teeth. This was due to an increase in total LE, and the increase in LE without dementia outweighed the increase in LE with dementia. These findings emphasize that maintaining more teeth is important for preventing this transition and achieving a longer dementia-free and total LE.

Comparison of the Findings

Our study reveals that transitions from non-dementia to dementia, non-dementia to death, and dementia to death differed depending on the number of teeth, with ≥20 teeth was associated with to longer dementia-free LE. Previous research has established a connection between better oral health and a reduced risk of dementia onset,[10-13] as well as an association between oral health and mortality.[28-30] Prior studies have also indicated relationships between having more teeth, effective oral health care, and longer LE without disability.[15,16] Our study extends the evidence that having more teeth is beneficial for longer dementia-free or total LE.

Regarding the transition from dementia to death, few studies have targeted community-dwelling older adults with longer follow-up periods. Recent studies conducted in long-term facilities reported that poor oral health was associated with mortality; however, in that study, the population was not limited to individuals with dementia.[31,32] This is in line with the current findings, demonstrating that having more teeth was associated with a lower risk of mortality among those with dementia.

Our results did not show a clear dose-response relationship between fewer teeth and dementia onset, despite the clear association between fewer teeth and mortality. Those with 1 to 9 teeth had the highest HR for dementia onset. Dementia variables are obtained from the public long-term care insurance system using municipal records; therefore, if people have related symptoms, they cannot be identified as having dementia unless they apply to the municipality. Tooth loss may also increase the risk of social isolation.[33,34] Those with 0 teeth may be isolated and may not receive a diagnosis owing to a lack of support for dementia by family and caregivers. This difficulty may lead to underreporting of dementia among individuals with 0 teeth. This suggests that our findings on the HR for participants with 0 teeth were relatively low owing to the bias associated with reporting dementia in these individuals.

Possible Mechanisms

Regarding the mechanisms of dementia-free LE that differed according to the number of teeth, the following reasons could be

Table 3
Associations Among the Number of Teeth, Dementia Onset, and All-Cause Mortality During a 10-Year Follow-Up (n = 44,083)

			Non-dementia to Dementia (n = 44,083)			Non-dementia to Death (n = 44,083)			Dementia to Death (n = 7605)		
			HR	95% CI	*P* Value	HR	95% CI	*P* Value	HR	95% CI	*P* Value
Number of teeth (Ref: ≥20 teeth)	10–19	Model 1	1.19	1.11–1.27	<.001	1.20	1.11–1.29	<.001	1.21	1.09–1.34	<.001
	1–9		1.27	1.19–1.35	<.001	1.43	1.34–1.54	<.001	1.23	1.17–1.36	<.001
	0		1.26	1.17–1.35	<.001	1.69	1.57–1.83	<.001	1.38	1.24–1.53	<.001
	10–19	Model 2	1.14	1.07–1.22	<.001	1.13	1.05–1.22	.001	1.18	1.07–1.32	.002
	1–9		1.15	1.08–1.22	<.001	1.27	1.19–1.37	<.001	1.20	1.09–1.33	<.001
	0		1.13	1.05–1.21	.001	1.47	1.36–1.59	<.001	1.33	1.19–1.48	<.001

Ref, Reference.
Model 1: Sex and age were adjusted.
Model 2: Model 1+ Education level, marital status, income, walking time, depression, drinking history, smoking history, and presence of comorbidities (diabetes, hypertension, stroke, heart diseases) were included.

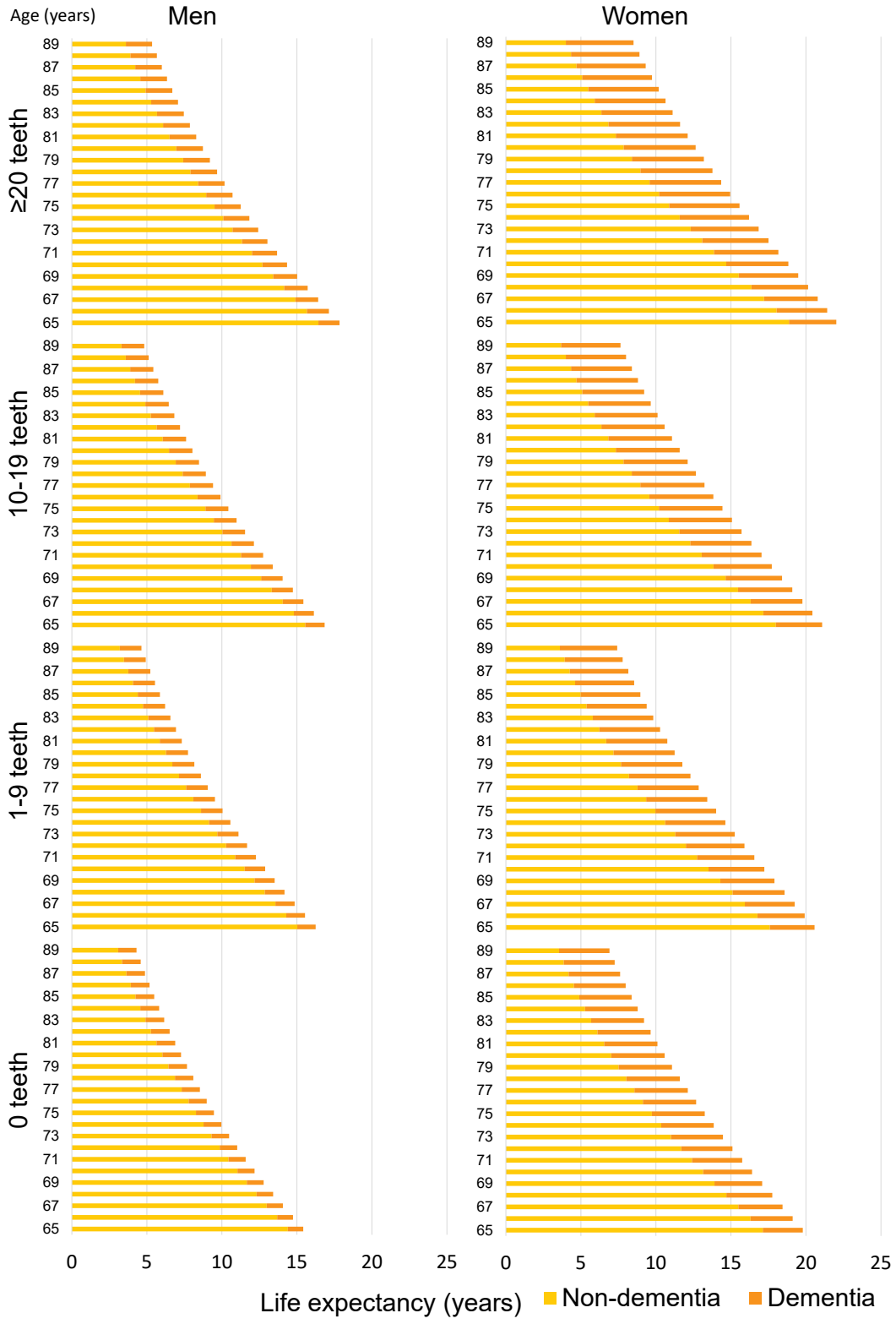

Fig. 1. LE with and without dementia at each age (65–89 years).

considered: first, having more teeth leads to maintaining nutritional status and food diversity,[14] as adequate nutrition was suggested to be important for maintaining cognitive function[35]; second, having fewer teeth has been reported to result in social isolation,[33,34] which is a risk factor for dementia onset[36]; third, fewer teeth may decrease brain stimulation, and periodontal disease, which is a primary cause of tooth loss, and can trigger inflammation that subsequently contributes to cognitive decline.[10,11]

Table 4
Difference in Total LE, Dementia-free LE, and LE With Dementia at 65 Years of Age According to the Number of Teeth

	Dementia-free LE	Differences in Dementia-free LE	LE With Dementia	Differences in LE With Dementia	Total LE	Differences in Total LE
Men						
≥20	16.43	+2.04	1.41	+0.39	17.84	+2.42
10–19	15.56	+1.16	1.29	+0.27	16.85	+1.43
1–9	15.03	+0.63	1.21	+0.19	16.24	+0.82
0	14.40	Ref	1.02	Ref	15.42	Ref
Women						
≥20	18.88	+1.75	3.15	+0.49	22.03	+2.24
10–19	17.99	+0.87	3.09	+0.42	21.08	+1.29
1–9	17.59	+0.47	2.99	+0.32	20.58	+0.79
0	17.12	Ref	2.67	Ref	19.79	Ref

Ref, Reference.
The values were estimated from the models including sex, age, education level, marital status, income, walking time, depression, drinking history, smoking history, and presence of comorbidities (diabetes, hypertension, stroke, heart diseases).

Public Health Implications

For public health implications, our study findings highlight the importance of maintaining a higher number of teeth for longer dementia-free LE. Our study showed that having more teeth is critical for prolonged dementia-free and total LE. To maintain the number of teeth, strategies enacted from older age are not sufficient, and a life-course approach is needed. First, the implementation of fluoride treatments and regulations on sugar-sweetened beverages could be considered important for preventing dental caries.[37-39] In addition, tobacco control is essential for reducing the incidence of periodontal diseases.[40] Further research is needed to elucidate the factors that prolong dementia-free LE, including the effectiveness of prosthetic dental interventions and preventive dental care.

Strengths and Limitations

This study has several limitations; first, the use of self-reported variables from the questionnaire as exposure variables and covariates. However, the validity of the number of teeth was previously confirmed.[17] Second, our follow-up period of approximately 10 years may be relatively short for assessing the life span of younger older adults, especially considering the current LE.[41] Our estimates are extrapolated calculations based on a limited study period; thus, the estimated LE may be biased due to the existence of right-censoring. Therefore, future studies with longer follow-up periods are warranted. However, our estimates from the age-adjusted models and the multistate modeling are similar to the official reports from the Ministry of Health, Labour, and Welfare in Japan,[27] and the assumption and estimate are considered plausible. Third, the baseline number of teeth was used as an exposure variable; therefore, we could not capture changes in oral health status during follow-up, including changes in oral status after dementia onset. Future studies should examine how changes in oral health affect this transition, particularly from dementia onset to death. Fourth, there might be a healthy survivor bias in our study, especially for very old participants. As our study estimated the LE based on the baseline data, the LE of those who were alive and functionally independent at the time of the survey may be longer than the average LE of the general population, especially for the older population. Moreover, those who joined the survey would be healthier than the general population; therefore, caution should be considered for generalization.

This study has several strengths; first, we used data on dementia onset and death from municipalities' records. Therefore, our data had a higher follow-up rate (the follow-up rate for the death and dementia records was 98.5%) and lower attrition bias. In addition, the diagnosis of dementia and death records in our study were reliable measurements compared with self-reported data.

Conclusions and Implications

Our findings indicate that having more teeth is associated with longer dementia-free and total LEs. These results suggest that public health policies aimed at preventing tooth loss are critical for extending both dementia-free LE and total LE.

Disclosures

The authors declare no conflicts of interest.

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Supplementary Data

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