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Assessing the effectivity of counting the number of teeth with their conditions to predict mortality: the OHSACA study

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Abstract

Background Although previous studies have reported associations between the number of teeth and all-cause mortality, the results vary depending on the tooth condition. Few previous studies have focused on the most effective method of counting the number of teeth to predict all-cause mortality. This study aimed to identify an effective method for counting the number of teeth according to their condition in order to predict all-cause mortality.

Methods This cohort study used data from the Oral Health Screening to Assess Keys of Aging Well (OHSACA) study and linked public dental check-ups and healthcare administrative datasets in Japan from 2018 to 2020. A total of 190,282 participants aged 75 years or older who underwent public dental checkups in Japan were evaluated for the study. The exposure in this study was the number of teeth and their condition, excluding the third molars. The outcome measure was all-cause mortality using the National Health Insurance Database of Japan.

Results The median observational period was 3.4 years (interquartile range, 2.8–3.8), and all-cause mortality was observed in 9,713 (12.0%) men and 6,242 (5.7%) women. Adjusted Cox proportional hazard models revealed a dose-dependent association between sound and filled teeth and the all-cause mortality (adjusted hazard ratios [95% confidence intervals] of 0, 1–5, 6–10, 11–15, 16–20, and ≥ 21 teeth for men: 1.74 [1.62, 1.87], 1.51 [1.41, 1.61], 1.42 [1.33, 1.51], 1.38 [1.29, 1.47], 1.15 [1.08, 1.22], and 1.00 [reference], respectively, for women: 1.69 [1.55, 1.85], 1.35 [1.24, 1.48], 1.24 [1.14, 1.34], 1.21 [1.12, 1.31], 1.17 [1.09, 1.26], and 1.00 [reference], respectively). The Net Reclassification Improvement of the sound + filled + decayed teeth count model decreased compared to that of the sound + filled teeth count model in both men and women.

Conclusions This study clarified the deleterious and beneficial associations between decayed and filled teeth and all-cause mortality. The total number of sound and filled teeth predicted all-cause mortality more accurately than the number of sound teeth alone, or the number of sound, filled, and decayed teeth combined.

Keywords Public dental checkups, method for counting teeth, older adults ≥ 75 years, claims data

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Background

According to the World Health Organization, poor oral health is a prevalent and critical concern in older adults [1, 2]. The number of teeth is a major indicator of oral health as low number of existing teeth is a predictor of a wide variety of health problems, including weight loss [3], diabetes [4], hypertension [5], cardiovascular disease [6], end-stage kidney disease [7], dementia [8], cancer [9], and even mortality [6].

Although multiple cohort studies have reported associations between the number of teeth and all-cause mortality [6], the cutoff values for tooth counts vary, with few studies being based on the self-reported number of teeth. Surveys based on patient self-reporting of tooth counts may result in slight underestimation and an inability to assess the condition of teeth [10]. The National Health and Nutrition Examination Survey, which included 24,029 adults in the US, showed that participants with decayed teeth had a significantly higher risk of all-cause and cardiovascular mortality than those without decayed teeth, suggesting that decayed teeth have a deleterious effect on all-cause and cardiovascular mortality [11]. Similarly, filled teeth with permanent restorations [12], have been shown to be associated with all-cause mortality. A Finnish cohort study including 231 patients with coronary artery disease (CAD) and 242 age- and sex-matched participants without CAD showed that those with filled teeth had a significantly lower risk of cardiovascular mortality than those without filled teeth, suggesting a beneficial effect of filled teeth on cardiovascular mortality [13]. The findings of these studies showed that different teeth have different effects on mortality. Thus, tooth counts that consider tooth condition may be more predictive of mortality than self-reported tooth counts. Improved prediction performance might help in making decisions about dental treatment or other prevention strategies. Few previous studies have focused on the most effective method of counting the number of teeth to predict all-cause mortality.

The present retrospective cohort study, including 190,282 older adults aged ≥ 75 y, aimed to identify the effective way to count the number of teeth with their condition for predicting all-cause mortality. The large sample size of this study enabled us to compare the clinical impact of sound, decayed teeth, and filled teeth on all-cause mortality.

Methods

Participants

This longitudinal study was part of the ongoing large cohort study from the Oral Health Screening to Assess Keys of Aging well (OHSAKA) study that aimed to identify factors contributing to healthy life expectancy among older adults aged ≥ 75 years. Eligible participants

in this retrospective cohort study were older adults aged ≥ 75 years who underwent annual dental checkups during the entry period between April 2018 and March 2020 in Osaka Prefecture, Japan. In Japan, most of the older population aged ≥ 75 years belong to the late-stage medical care system for the older, besides a minority of persons aged 65–74 years with disabilities. A total of 1,100,572 eligible beneficiaries belonging to the late-stage medical care system for the elderly in Osaka Prefecture were insured as of April 1, 2018, of which 256,772 underwent annual dental checkups. The baseline date was the first dental checkup during the entry period. We finally included 190,282 participants aged ≥ 75 years at the baseline checkup after excluding 5,182 participants with unavailable information on long-term care insurance in a single city, 1,850 aged < 75 years at the baseline checkup, 27,503 with < 6 months of insurance period before the baseline checkup, 31,874 with missing baseline data, and 31 that had no follow-up period after the baseline checkup.

All insurance and medical claim data were retrieved from the National Health Insurance Database of Japan (Kokuho database: KDB). All dental checkup data were provided by the Extended Association of Medical Care Systems for Older Senior Citizens of Osaka Prefecture, Japan.

Measurements

The primary exposure in this study was the maximum number of teeth (28), excluding the third molars. All teeth were diagnosed as sound, filled, or decayed by dentists at their dental clinics. Three methods were used to count the number of teeth based on their condition: sound teeth (S), sound and filled teeth (S + F), and sound, filled, and decayed teeth combined (S + F + D). The participants were divided into six groups based on the number of teeth: 0, 1–5, 6–10, 11–15, 16–20, and ≥ 21 , in each tooth counting method. Baseline variables included age, sex, body mass index ($\text{BMI} = \text{body weight [kg]} / \text{height}^2 [\text{m}^2]$), and the self-reported smoking status (never, past, or current smoking) at the baseline dental checkup. Baseline functional status was ascertained by certification of long-term care (LTC) needs before the baseline dental checkup. In Japan, LTC needs are based on a 74-item questionnaire on activities of daily living and physicians' medical diagnoses. The Care Needs Certification Board of the municipal government determines the certification of LTC needs and assigns seven care needs levels: requiring support 1 and 2 and requiring long-term care 1, 2, 3, 4, and 5. The baseline use of antidiabetic, antihypertensive, lipid-lowering, antiplatelet, and antidementia drugs was determined based on the history of one or more prescriptions within six months before the baseline dental checkup. Antidiabetic drugs were defined as A10 code

of anatomical therapeutic chemical classification system by the World Health Organization [14]; antiplatelet drugs as B01AC [15]; beta blockers as C07 [16]; calcium channel blockers as C08 [14]; renin-angiotensin system (RAS) blockers as C09 [14]; lipid-lowering drugs as C10AA, C10AX09, and C10BA [17]; antidementia drugs as N06DA and N06DX01 [16], respectively. The requirement for kidney replacement therapy, such as hemodialysis, peritoneal dialysis, or kidney transplantation, was determined based on the history of one or more medical claims within 6 months before the baseline dental checkup [18]. Hospitalization ascertained medical claims based on the history of one or more hospitalizations within six months before the baseline dental checkup. Medical costs during 6 months (<10,000; 10,000–49,999; 50,000–99,999; 100,000–199,999; 200,000–299,999; and ≥300,000 yen) before the baseline dental checkup were calculated using medical receipts on medical procedures, prescriptions, Diagnosis Procedure Combination, and fee-for-service payment [19].

The outcome measure of this study was the incidence of all-cause mortality, which was verified as the reason for loss of insurance eligibility. The observational period was defined as the number of days from the baseline date to (i) death, (ii) loss of insurance eligibility, or (iii) March 2022, whichever occurred first.

Statistical analyses

Continuous variables are expressed as medians (25–75%), as appropriate, and categorical variables are expressed as numbers (proportions). The cumulative probability of all-cause mortality was estimated using the Kaplan–Meier method and compared using the log-rank test. The association between the number of teeth and all-cause mortality was assessed using unadjusted and adjusted Cox proportional hazard models. The proportional hazard assumption was tested using the Schoenfeld residuals. Hazard ratios (HRs) with 95% confidence intervals (CIs) for the six groups of each tooth count method were calculated in unadjusted and multivariable-adjusted models, including the age of participants, LTC needs levels, BMI, self-reported smoking status, use of antidiabetic, antiplatelet, beta-blockers, calcium channel blockers, RAS blockers, lipid-lowering, and antidementia drugs, requiring kidney replacement therapy, hospitalization, and medical costs as covariates. Several previous studies have reported sex differences in the association between the number of teeth and all-cause mortality [20, 21]. To assess in detail the most effective method of counting teeth for predicting all-cause mortality, we stratified all analyses by sex.

To evaluate tooth counting methods for predicting all-cause mortality, we utilized risk classification improvement by sequentially adding filled and decayed teeth to

assess the improvement over the baseline model consisting of sound teeth. The risk classification improvement was determined through reclassification analysis [20, 21], estimating the net reclassification improvement (NRI) separately among the tooth count methods compared with the sound teeth count model as the base. The NRI can be calculated by computing the difference between the proportions of individuals moving up and those moving down among individuals who develop events, and subtracting the corresponding difference among those who do not develop events [22]. For individuals who experience events, an increase in predicted probability is classified as an upward movement ($v(i) = 1$), whereas a decrease is classified as a downward movement ($v(i) = -1$) [22]. The NRI was calculated by considering all variables continuous and excluding self-reported smoking status, which was treated as the only categorical variable among the adjusted variables.

We used R statistical software, version 4.1.3 (R Development Core Team, 2020) for analysis. All statistical tests were 2-sided, and $P < 0.05$ was considered statistically significant.

Results

Of the 1,100,572 beneficiaries of the late-stage medical care system for the elderly in Osaka Prefecture in April 2018, 23.3% (256,722 participants) underwent annual dental checkups in Osaka during the entry period. The baseline characteristics of the 190,282 participants, stratified by six categories based on the number of sound teeth, are presented in Tables 1 and 2. Participants with a large number of sound teeth were younger and had a lower prevalence of antidiabetic, antiplatelet, beta-blocker, calcium channel blocker, RAS blocker, and antidementia drug use and rate of hospitalization.

During the median observational period of 3.4 years (interquartile range, 2.8–3.8), all-cause mortality was observed in 4,161 (17.3%), 2,330 (12.1%), 1,558 (9.5%), 971 (8.4%), 486 (7.2%), 207 (6.9%) for men and 2,724 (8.4%), 1,584 (5.2%), 1,111 (4.4%), 530 (3.9%), 227 (3.9%), 66 (3.4%) for women with 0, 1–5, 6–10, 11–15, 16–20, and ≥21 sound teeth, respectively. The cumulative probabilities of all-cause mortality in 81,004 men and 109,278 women were significantly associated with the number of sound teeth (Fig. 1a, b); sound and filled teeth (Fig. 1c, d); and sound, filled, and decayed teeth combined (Fig. 1e, f). The proportional hazards assumption was confirmed to hold by graphically assessing Schoenfeld residuals.

A dose-dependent association was found between the number of sound and filled teeth (S + F), number of decayed teeth (S + F + D), and cumulative probability of all-cause mortality. In contrast, the dose-dependent association between the number of sound teeth (S)

Table 1 Clinical characteristics of 81,004 men stratified by number of sound teeth

	Number of teeth (Sound teeth)					
	0	1–5	6–10	11–15	16–20	≥ 21
Number	24,029	19,276	16,414	11,522	6,754	3,009
Age, year	81 (78–84)	79 (77–83)	79 (77–82)	78 (76–81)	78 (76–81)	78 (76–80)
Body Mass Index, n (%)						
< 18.5	1,844 (7.7)	1,120 (5.8)	778 (4.7)	509 (4.4)	293 (4.3)	118 (3.9)
18.5–24.9	17,275 (71.9)	14,177 (73.5)	12,008 (73.2)	8,510 (73.9)	4,982 (73.8)	2,251 (74.8)
25.0–29.9	4,560 (19.0)	3,713 (19.3)	3,401 (20.7)	2,333 (20.2)	1,386 (20.5)	603 (20.0)
≥ 30	350 (1.5)	266 (1.4)	227 (1.4)	170 (1.5)	93 (1.4)	37 (1.2)
Long-term care needs levels						
None	17,638 (73.4)	15,612 (81.0)	13,851 (84.4)	10,002 (86.8)	5,953 (88.1)	2,696 (89.6)
Requiring support 1	2,989 (12.4)	1,759 (9.1)	1,269 (7.7)	727 (6.3)	366 (5.4)	150 (5.0)
2	1,273 (5.3)	666 (3.5)	470 (2.9)	335 (2.9)	146 (2.2)	59 (2.0)
Requiring long-term care 1	1,133 (4.7)	702 (3.6)	432 (2.6)	256 (2.2)	149 (2.2)	50 (1.7)
2	501 (2.1)	248 (1.3)	197 (1.2)	101 (0.9)	78 (1.2)	25 (0.8)
3	251 (1.0)	149 (0.8)	94 (0.6)	46 (0.4)	36 (0.5)	12 (0.4)
4	175 (0.7)	91 (0.5)	70 (0.4)	36 (0.3)	15 (0.2)	12 (0.4)
5	69 (0.3)	49 (0.3)	31 (0.2)	19 (0.2)	11 (0.2)	5 (0.2)
Smoking, n (%)						
Never	6,161 (25.6)	5,406 (28.0)	4,923 (30.0)	3,765 (32.7)	2,347 (34.7)	1,076 (35.8)
Past	14,345 (59.7)	11,580 (60.1)	9,754 (59.4)	6,642 (57.6)	3,793 (56.2)	1,681 (55.9)
Current	3,523 (14.7)	2,290 (11.9)	1,737 (10.6)	1,115 (9.7)	614 (9.1)	252 (8.4)
Medicine, n (%)						
Antidiabetic drugs	5,145 (21.4)	3,760 (19.5)	3,085 (18.8)	2,067 (17.9)	1,079 (16.0)	456 (15.2)
Antiplatelet drugs	7,975 (33.2)	6,034 (31.3)	4,973 (30.3)	3,272 (28.4)	1,880 (27.8)	821 (27.3)
Beta-blockers	3,402 (14.2)	2,661 (13.8)	2,154 (13.1)	1,502 (13.0)	895 (13.3)	370 (12.3)
Calcium channel blockers	9,722 (40.5)	7,706 (40.0)	6,464 (39.4)	4,490 (39.0)	2,681 (39.7)	1,147 (38.1)
RAS blockers	9,453 (39.3)	7,533 (39.1)	6,348 (38.7)	4,487 (38.9)	2,606 (38.6)	1,182 (39.3)
Lipid-lowering drugs	7,192 (29.9)	5,690 (29.5)	5,053 (30.8)	3,509 (30.5)	2,080 (30.8)	920 (30.6)
Antidementia drugs	1,173 (4.9)	723 (3.8)	521 (3.2)	316 (2.7)	179 (2.7)	80 (2.7)
Hospitalization, n (%)	3,260 (13.6)	2,305 (12.0)	1,875 (11.4)	1,285 (11.2)	704 (10.4)	286 (9.5)
Kidney replacement therapy, n (%)	168 (0.7)	146 (0.8)	93 (0.6)	74 (0.6)	30 (0.4)	12 (0.4)
Medical costs for 6 months, yen, n (%)						
< 10,000	1,159 (4.8)	899 (4.7)	783 (4.8)	531 (4.6)	334 (4.9)	145 (4.8)
10,000–49,999	1,788 (7.4)	1,551 (8.0)	1,419 (8.6)	1,094 (9.5)	662 (9.8)	286 (9.5)
50,000–99,999	3,306 (13.8)	2,971 (15.4)	2,655 (16.2)	1,985 (17.2)	1,193 (17.7)	564 (18.7)
100,000–199,999	6,458 (26.9)	5,481 (28.4)	4,683 (28.5)	3,305 (28.7)	1,985 (29.4)	893 (29.7)
200,000–299,999	4,057 (16.9)	3,200 (16.6)	2,653 (16.2)	1,810 (15.7)	1,043 (15.4)	425 (14.1)
≥ 300,000	7,261 (30.2)	5,174 (26.8)	4,221 (25.7)	2,797 (24.3)	1,537 (22.8)	696 (23.1)

Data are presented as median (25%–75%) or n (%)

RAS Renin-angiotensin system

and cumulative probability of all-cause mortality was moderate.

Adjusted Cox proportional hazard models showed a dose-dependent association between the number of sound and filled teeth (S+F) and all-cause mortality (adjusted HRs [95% CIs] of 0, 1–5, 6–10, 11–15, 16–20, and ≥ 21 teeth for men: 11.74 [1.62, 1.87], 1.51 [1.41, 1.61], 1.42 [1.33, 1.51], 1.38 [1.29, 1.47], 1.15 [1.08, 1.22], and 1.00 [reference], respectively, for women: 1.69 [1.55, 1.85], 1.35 [1.24, 1.48], 1.24 [1.14, 1.34], 1.21 [1.12, 1.31], 1.17 [1.09, 1.26], and 1.00 [reference], respectively) (Table 3). Adjusted Cox proportional hazard

models showed a dose-dependent association between the number of sound, filled, and decayed teeth combined (S + F + D) and the all-cause mortality (adjusted HRs [95% CIs] of 0, 1–5, 6–10, 11–15, 16–20, and ≥ 21 teeth for men: 1.67 [1.55, 1.79], 1.41 [1.31, 1.51], 1.31 [1.23, 1.40], 1.34 [1.26, 1.43], 1.16 [1.09, 1.23], and 1.00 [reference], respectively, for women: 1.57 [1.43, 1.73], 1.34 [1.22, 1.47], 1.19 [1.10, 1.29], 1.16 [1.07, 1.26], 1.11 [1.03, 1.19], and 1.00 [reference], respectively) (Table 3).

Table 4 compares the models for sound teeth (S), sound and filled teeth (S+F), and sound, filled, and decayed teeth combined (S + F + D). Continuous NRI

Table 2 Clinical characteristics of 109,278 women stratified by number of sound teeth

	Number of teeth (Sound teeth)					
	0	1–5	6–10	11–15	16–20	≥ 21
Number	32,341	30,293	25,376	13,482	5,834	1,952
Age, year	81 (78–85)	79 (77–83)	79 (77–82)	78 (76–81)	78 (76–81)	78 (76–81)
Body Mass Index, n (%)						
< 18.5	4,135 (12.8)	3,183 (10.5)	2,547 (10.0)	1,334 (9.9)	562 (9.6)	197 (10.1)
18.5–24.9	22,381 (69.2)	21,550 (71.1)	18,196 (71.7)	9,790 (72.6)	4,267 (73.1)	1,489 (76.3)
25.0–29.9	5,166 (16.0)	4,953 (16.4)	4,116 (16.2)	2,121 (15.7)	904 (15.5)	237 (12.1)
≥ 30	659 (2.0)	607 (2.0)	517 (2.0)	237 (1.8)	101 (1.7)	29 (1.5)
Long-term care needs levels						
None	19,029 (58.8)	20,802 (68.7)	18,372 (72.4)	10,367 (76.9)	4,500 (77.1)	1,529 (78.3)
Requiring support 1	6,855 (21.2)	5,141 (17.0)	3,822 (15.1)	1,710 (12.7)	727 (12.5)	222 (11.4)
2	2,830 (8.8)	2,032 (6.7)	1,531 (6.0)	691 (5.1)	308 (5.3)	92 (4.7)
Requiring long-term care 1	2,192 (6.8)	1,427 (4.7)	1,016 (4.0)	437 (3.2)	193 (3.3)	63 (3.2)
2	753 (2.3)	485 (1.6)	362 (1.4)	149 (1.1)	58 (1.0)	23 (1.2)
3	357 (1.1)	227 (0.7)	144 (0.6)	68 (0.5)	26 (0.4)	8 (0.4)
4	237 (0.7)	139 (0.5)	97 (0.4)	48 (0.4)	15 (0.3)	12 (0.6)
5	88 (0.3)	40 (0.1)	32 (0.1)	12 (0.1)	7 (0.1)	3 (0.2)
Smoking, n (%)						
Never	28,573 (88.3)	27,265 (90.0)	23,165 (91.3)	12,419 (92.1)	5,399 (92.5)	1,804 (92.4)
Past	2,251 (7.0)	1,828 (6.0)	1,370 (5.4)	693 (5.1)	288 (4.9)	97 (5.0)
Current	1,517 (4.7)	1,200 (4.0)	841 (3.3)	370 (2.7)	147 (2.5)	51 (2.6)
Medicine, n (%)						
Antidiabetic drugs	4,121 (12.7)	3,518 (11.6)	2,768 (10.9)	1,380 (10.2)	602 (10.3)	186 (9.5)
Antiplatelet drugs	8,556 (26.5)	7,256 (24.0)	5,704 (22.5)	2,950 (21.9)	1,233 (21.1)	421 (21.6)
Beta-blockers	3,596 (11.1)	3,107 (10.3)	2,454 (9.7)	1,268 (9.4)	552 (9.5)	195 (10.0)
Calcium channel blockers	13,755 (42.5)	12,438 (41.1)	9,901 (39.0)	5,066 (37.6)	2,199 (37.7)	712 (36.5)
RAS blockers	12,334 (38.1)	10,886 (35.9)	8,596 (33.9)	4,377 (32.5)	1,883 (32.3)	616 (31.6)
Lipid-lowering drugs	12,954 (40.1)	12,812 (42.3)	10,925 (43.1)	5,992 (44.4)	2,657 (45.5)	911 (46.7)
Antidementia drugs	1,916 (5.9)	1,263 (4.2)	963 (3.8)	404 (3.0)	167 (2.9)	55 (2.8)
Hospitalization, n (%)	3,136 (9.7)	2,572 (8.5)	2,002 (7.9)	1,059 (7.9)	426 (7.3)	128 (6.6)
Kidney replacement therapy, n (%)	96 (0.3)	75 (0.2)	54 (0.2)	28 (0.2)	12 (0.2)	8 (0.4)
Medical costs for 6 months, yen, n (%)						
< 10,000	1,153 (3.6)	1,110 (3.7)	948 (3.7)	560 (4.2)	247 (4.2)	89 (4.6)
10,000–49,999	2,056 (6.4)	2,231 (7.4)	2,056 (8.1)	1,192 (8.8)	516 (8.8)	194 (9.9)
50,000–99,999	4,530 (14.0)	4,689 (15.5)	4,215 (16.6)	2,249 (16.7)	992 (17.0)	325 (16.6)
100,000–199,999	9,649 (29.8)	9,516 (31.4)	7,763 (30.6)	4,245 (31.5)	1,887 (32.3)	619 (31.7)
200,000–299,999	6,105 (18.9)	5,401 (17.8)	4,529 (17.8)	2,286 (17.0)	985 (16.9)	300 (15.4)
≥ 300,000	8,848 (27.4)	7,346 (24.2)	5,865 (23.1)	2,950 (21.9)	1,207 (20.7)	425 (21.8)

Data are presented as median (25%–75%) or n (%)

RAS, renin-angiotensin system

was calculated using multivariable-adjusted models that included the age of participants; BMI; use of antidiabetic, antiplatelet, antidementia, lipid-lowering drugs, beta-blockers, calcium channel blockers, and RAS blockers; requiring kidney replacement therapy; hospitalization; and medical costs as covariates.

The NRI of the sound and filled teeth (S + F) count model and the sound, filled, and decayed teeth combined (S + F + D) count model was higher than that of the sound teeth (S) count model in both men and women (Table 4). The NRI of the sound, filled, and decayed teeth combined (S + F + D) count models were lower than that of the

sound and filled teeth (S + F) count models in both men and women (Table 4).

Discussion

The present retrospective cohort study, which included 190,282 older adults aged ≥ 75 years, clarified the deleterious and beneficial associations between decayed and filled teeth and all-cause mortality. The total number of sound and filled teeth (S + F) predicted all-cause mortality more accurately than sound teeth (S) only or sound, filled, and decayed teeth combined (S + F + D), suggesting that the diagnosis of tooth conditions is clinically relevant

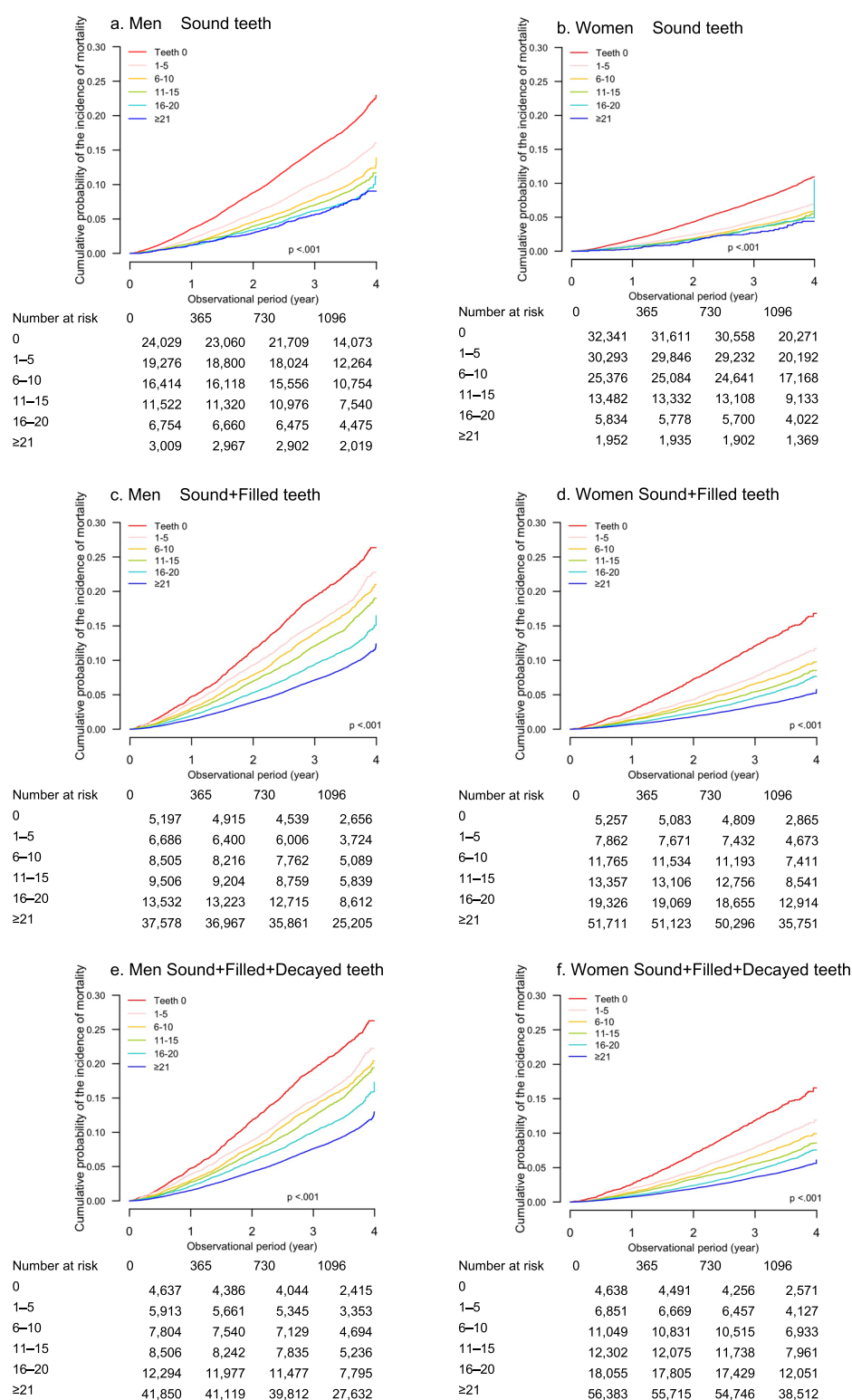


Fig. 1 Cumulative probabilities of the all-cause mortality. Cumulative probabilities of the all-cause mortality in 63,638 men and 72,669 women in the total number of the sound teeth (**a, b**), the sound teeth + filled teeth (**c, d**), the sound teeth + filled teeth + decayed teeth (**e, f**)

Table 3 Association of number of teeth and mortality (81,004 men and 109,278 women)

		Hazard Ratio (95% Confidence Interval)					
		Number of teeth					
		0	1–5	6–10	11–15	16–20	≥ 21
Men	Observational period, year	3.3 (2.6–3.8)	3.4 (2.7–3.8)	3.4 (2.8–3.8)	3.4 (2.8–3.8)	3.4 (2.8–3.8)	3.4 (2.8–3.8)
	Mortality, n (%)	4,161 (17.3)	2,330 (12.1)	1,558 (9.5)	971 (8.4)	486 (7.2)	207 (6.9)
	Unadjusted Model						
	S	2.68 (2.33, 3.08)	1.79 (1.55, 2.06)	1.39 (1.20, 1.60)	1.24 (1.06, 1.43)	1.05 (0.89, 1.24)	1.00 (reference)
	Adjusted Models*						
	S	1.58 (1.38, 1.82)	1.30 (1.12, 1.50)	1.13 (0.98, 1.31)	1.11 (0.95, 1.29)	0.99 (0.84, 1.17)	1.00 (reference)
	S + F	1.74 (1.62, 1.87)	1.51 (1.41, 1.61)	1.42 (1.33, 1.51)	1.38 (1.29, 1.47)	1.15 (1.08, 1.22)	1.00 (reference)
Women	Observational period, year	3.4 (2.7–3.8)	3.4 (2.8–3.8)	3.4 (2.8–3.8)	3.4 (2.8–3.8)	3.4 (2.8–3.8)	3.5 (2.8–3.8)
	Mortality, n (%)	2,724 (8.4)	1,584 (5.2)	1,111 (4.4)	530 (3.9)	227 (3.9)	66 (3.4)
	Unadjusted Model						
	S	2.58 (2.02, 3.30)	1.56 (1.22, 2.00)	1.30 (1.02, 1.67)	1.17 (0.91, 1.52)	1.15 (0.88, 1.51)	1.00 (reference)
	Adjusted Models*						
	S	1.43 (1.12, 1.82)	1.16 (0.91, 1.48)	1.11 (0.87, 1.42)	1.14 (0.89, 1.48)	1.18 (0.90, 1.55)	1.00 (reference)
	S + F	1.69 (1.55, 1.85)	1.35 (1.24, 1.48)	1.24 (1.14, 1.34)	1.21 (1.12, 1.31)	1.17 (1.09, 1.26)	1.00 (reference)
	S + F + D	1.57 (1.43, 1.73)	1.34 (1.22, 1.47)	1.19 (1.10, 1.29)	1.16 (1.07, 1.26)	1.11 (1.03, 1.19)	1.00 (reference)

HR Hazard ratio, CI Confidence interval, S + F + D Sound teeth + filled teeth + decayed teeth, S + F Sound teeth + filled teeth, S Sound teeth

*Adjusting for age (year), LTC needs levels, Body Mass Index (kg/m², < 18.5; 18.5–24.9; 25.0–29.9; ≥ 30), smoking (never; past; current), use of antidiabetic drugs, antiplatelet drugs, beta-blockers, calcium channel blockers, RAS blockers, lipid-lowering drugs, and antidementia drugs, kidney replacement therapy (hemodialysis, peritoneal dialysis, and kidney transplantation), hospitalization, and 6-month medical costs (< 10,000; 10,000–49,999; 50,000–99,999; 100,000–199,999; 200,000–299,999; ≥ 300,000 yen)

Table 4 Predictive method of counting teeth by reclassification

	Continuous NRI (95% CI)	IDI (95% CI)
Men		
S* vs. S + F	0.057 (0.033, 0.074)	0.002 (0.001, 0.003)
S* vs. S + F + D	0.021 (0.000, 0.043)	0.001 (0.000, 0.002)
S + F* vs. S + F + D	−0.101 (−0.121, −0.061)	−0.001 (−0.001, −0.001)
Women		
S* vs. S + F	0.073 (0.045, 0.101)	0.001 (0.001, 0.002)
S* vs. S + F + D	0.042 (0.020, 0.082)	0.001 (0.000, 0.002)
S + F* vs. S + F + D	−0.109 (−0.137, −0.059)	0.000 (−0.001, 0.000)

NRI Net reclassification improvement, IDI Integrated discrimination improvement, S + F + D sound teeth + filled teeth + decayed teeth, S + F sound teeth + filled teeth, S, sound teeth

*reference; Adjusting for age (year), LTC needs levels, Body Mass Index (kg/m², < 18.5; 18.5–24.9; 25.0–29.9; ≥ 30), use of antidiabetic drugs, antiplatelet drugs, beta-blockers, calcium channel blockers, RAS blockers, lipid-lowering drugs, and antidementia drugs, kidney replacement therapy (hemodialysis, peritoneal dialysis, and kidney transplantation), hospitalization, and 6-month medical costs

for assessing the risk of all-cause mortality in the older population. The large sample size enabled us to compare the clinical impacts on all-cause mortality among sound, filled, and decayed teeth combined (S + F + D) and to identify the most effective way to count the number of teeth for predicting the all-cause mortality.

Although multiple studies have identified the number of non-missing teeth as a significant predictor of all-cause mortality, few have assessed the impact of each

tooth's clinical condition on all-cause mortality. A small Finnish cohort study, the Evergreen project, assessed the association between tooth conditions categorized into missing, sound, decayed, and filled teeth and 10-year mortality in 226 adults aged 80 years [20]. The number of missing teeth was positively associated with the incidence of all-cause mortality in the unadjusted model, whereas the number of filled teeth was negatively associated with the incidence of all-cause mortality, which is consistent with the results of the present study. The number of sound and decayed teeth was not significantly associated with all-cause mortality. In the present study, the multivariate-adjusted model identified only the number of missing teeth as a significant predictor of all-cause mortality. The small sample size of this cohort study hindered statistically meaningful analyses to assess the association between tooth condition and all-cause mortality. The large sample size of the present study enabled us to compare the predictive power of each tooth condition for the incidence of all-cause mortality.

The current study revealed that predicting all-cause mortality is more accurate when considering the counts of sound and filled teeth than when solely considering sound teeth or including sound, filled, and decayed teeth combined. This finding indicates that functional recovery can be achieved through restoration or prosthodontic treatment even if the natural tooth structure is lost. Decayed teeth may be indicative of an increased risk of all-cause mortality, either due to their lack of structural

restoration, leading to functional impairment, or as a potential source of chronic inflammation. The association of decayed and filled teeth with all-cause mortality in the present study may have been confounded by unmeasured confounding factors, including socioeconomic status. Previous cross-sectional studies have shown that low levels of education [23–26] and income [24–27] were associated with the prevalence of decayed teeth, whereas other studies have reported that high levels of education [27–30] and income [30] were associated with the prevalence of filled teeth. In the present study, participants with a higher number of decayed teeth and a lower number of filled teeth presumably had lower levels of education and income, which might have put them at a higher risk of all-cause mortality [31, 32]. Another potential confounding factor is social support, including marital status. Several cross-sectional studies have suggested a clinical impact of marital status on dental caries. Single adults are more vulnerable to decayed teeth [23, 30] and are likely to have fewer filled teeth than married adults [30]. Given that several systematic reviews have demonstrated a beneficial effect of marital status on all-cause mortality even in older adults [33, 34], single participants in the present study might have a higher number of decayed teeth, lower number of filled teeth, and higher risk of all-cause mortality. The mechanism underlying the association between the number of decayed and filled teeth and all-cause mortality should be carefully investigated in well-designed cohort studies.

The present study has several limitations. First, the validity of the findings of this study should be verified in a population aged <75 years. The Nutritional Health and Nutrition Examination Survey, including 24,029 adults in the US, reported that an association between untreated caries and the incidence of all-cause mortality were comparable between subgroups of age of <70 and ≥70 years [11]. The clinical impact of decayed and filled teeth on all-cause mortality should be assessed in younger populations from different countries. Second, because cause-specific mortality data were not available in the present study, the clinical impact of decayed and filled teeth on cause-specific mortality was not assessed in the present study. Few cohort studies reported that the number of teeth was inversely associated with the incidence of all-cause and cardiovascular mortality, but not stroke mortality [11, 21], whereas others identified the number of teeth as a significant predictor of stroke mortality [35, 36]. The clinical effect of the number of teeth on cause-specific mortality, particularly stroke mortality, should be investigated in future studies. Third, the association between number of teeth and all-cause mortality may have been affected by unmeasured confounding factors, including depressive disorders. The association between depression and an increased risk of all-cause

mortality has been widely recognized [37]. A previous cohort study has reported an association between tooth loss and depressive disorders [38]. Another systematic review showed that patients with depressive disorders had poor oral status, such as tooth loss, which was significantly higher than that in the general population [39]. Other unmeasured confounding factors included health behaviors and social support. Health behaviors, such as oral hygiene practices [40, 41] and dietary habits [42–44], were associated with tooth loss, and both oral hygiene practices [45–47] and dietary habits [48–50] were reported to be risk factors for mortality. Social support was also shown to be associated with both tooth loss [51–53] and mortality [54–56]. Thus, in the present study, all-cause mortality was associated with the number of teeth, and this association may have been confounded by depressive disorders, health behaviors, and social support. A well-designed future study is essential to verify the findings of the present study. Fourth, the public dental checkup was offered free of charge as a public health service; however, participation was voluntary. Consequently, only a subset of the 1,100,572 individuals enrolled in Osaka Prefecture's late-stage elderly medical care system actually underwent the checkup. This may have introduced a selection bias favoring individuals with relatively high health consciousness, whose health behaviors may have affected their mortality risk [57]. In addition, individuals living in remote areas with limited access to dental and medical services may have been inadvertently excluded. These selection biases could have led to an underestimation of mortality incidence; therefore, caution is warranted when generalizing the findings to the broader population of late-stage older adults.

In conclusion, the present study clarified the deleterious and beneficial associations between decayed and filled teeth and all-cause mortality. The total number of sound and filled teeth (S + F) predicted all-cause mortality more accurately than the number of sound teeth (S) alone or the number of sound, filled, and decayed teeth combined (S + F + D). This finding suggests that the diagnosis of tooth conditions is clinically relevant for assessing the risk of all-cause mortality in older adults.

Abbreviations

KDB	Kokuho database
S	Sound teeth
S + F	Sound and filled teeth
S + F + D	Sound, filled, and decayed teeth
BMI	Body mass index
LTC	Long-term care
HRs	Hazard ratios
Cis	Confidence intervals
NRI	The net reclassification improvement

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12903-025-07275-6>.

Supplementary Material 1.

Supplementary Material 2.

Data sharing statement

The data are not publicly available. These data originate from the Wider-Area Union for the Medical Care System for Elderly People in Osaka Prefecture. Restrictions apply to the availability of these data, which used under license and ethical approval.

Authors' contributions

Conceptualization: [N.O., R.Y., T.M., and K.I.], Methodology: [N.O. and R.Y.], Formal analysis: [N.O.], Investigation: [N.O.], Writing – original draft preparation: [N.O. and R.Y.]; Writing – review and editing: [R.Y., T.M., S.T., M.S., A.K., and K.I.], Funding acquisition: [R.Y.], Resources: [R.Y.], Supervision: [T.M. and K.I.], Project administration: [R.Y.]

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Data availability

The data are not publicly available. These data originate from the Wider-Area Union for the Medical Care System for Elderly People in Osaka Prefecture. Restrictions apply to the availability of these data, which used under license and ethical approval.

Declarations

Ethics approval and consent to participate

The study protocol was approved by the ethics committees of Health and Counseling Center, Osaka University (No. 2) and Graduate School of Dentistry (No. R4–M2–1), Osaka University. The data used from the Kokuho database (KDB) was obtained from the Wider-Area Union for the Medical Care System for Elderly People in Osaka Prefecture and underwent a de-identification process to ensure the privacy and confidentiality of individuals. The research team had no access to personally identifiable information, and all data handling followed stringent data security and privacy protection standards. Informed consent was not required for this study using KDB data, as it involved analysis solely of de-identified data derived from pre-existing medical claims records.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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