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CLINICAL RESEARCH

Dental prosthesis use and mortality: A time-varying exposure analysis with machine learning

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ABSTRACT

Statement of problem. Tooth loss has been associated with an increased risk of mortality, and dental prosthesis use may mitigate the effect by recovering masticatory function. However, most studies investigated dental prosthesis use only at baseline and did not consider changes during the follow-up.

Purpose. The purpose of this prospective cohort study was to examine the association between dental prosthesis use as a time-varying exposure and mortality in older Japanese adults.

Material and methods. Data from the Japan Gerontological Evaluation Study were used, targeting independent adults aged ≥65 years. The baseline questionnaire survey was conducted in 2013, and all-cause mortality data of participants up to 2022 were obtained from the local municipality database (n=47 698; median follow-up: 9.2 years). The 2016 and 2019 questionnaire surveys collected time-varying exposure and covariate information. A doubly robust estimator with ensemble machine learning and controlling for covariates was used to estimate survival probability. The analysis was conducted on all participants, those with <20 natural teeth and those with <10 natural teeth.

Results. Of the participants, 19.0% died during follow-up and 55.8% used dental prostheses at baseline. Consistent dental prosthesis use was associated with higher survival probability than consistent nonuse (average treatment effect [ATE]=3.7% points; 95% confidence interval [CI]: 0.3, 7.0). Greater associations were revealed for those with fewer natural teeth (for those with <10 natural teeth, ATE=10.0% points; 95% CI: −0.6, 20.6).

Conclusions. Consistent dental prosthesis use was associated with increased survival probability in older Japanese adults. This association was greater among participants with fewer natural teeth. (J Prosthet Dent xxxx;xxx:xxx-xxx)

Tooth loss is a prevalent oral condition that influences the well-being of older adults.[1] More than 30% of individuals aged ≥70 were reported to be edentulous in 2021.[2] The total number of people with tooth loss has been increasing because of the aging population, whereas age-standardized prevalence has been decreasing.[3] By 2050, 8.6 million people are projected to be edentulous in the United States.[4] A meta-analysis revealed that malnutrition, a risk factor for mortality among older adults,[5] is 1.2 times more prevalent in older adults having <20 natural teeth.[6] Moreover, previous studies revealed that having fewer natural teeth was associated with social isolation,[7–9] a significant risk factor of mortality.[10] Hence, tooth loss can be a risk factor for all-cause mortality.[11–15] In particular, a systematic review summarized 5 previous cohort studies with ≥10 years of follow-up and reported pooled estimates 1.39 times higher hazard for all-cause mortality among edentulous older adults.[15]

The replacement of lost teeth with dental prostheses has been reported to improve masticatory function.[16] Dental prosthesis use with dietary advice reportedly

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Clinical Implications

This study investigated the association between the continuous use of dental prostheses and all-cause mortality in Japanese older adults. The machine-learning-based analysis found that continuous dental prosthesis use was associated with a 3.9% point lower mortality in older Japanese adults over 9 years. Providing dental prostheses may mitigate the effect of tooth loss on mortality.

improves nutritional status,[17] which may mitigate the effect of tooth loss on mortality. However, few studies, compared with many studies on tooth loss and mortality, have been conducted on whether dental prostheses mitigate the impact of tooth loss on mortality, and the previous studies have been limited in terms of small sample sizes and inadequate confounder adjustments.[11,18] Recently, 2 studies involving the clinical examination of adults with tooth loss in the United States analyzed the propensity score and revealed reduced mortality of over 20 years among individuals using complete[19] or removal partial dentures,[20] assessed at baseline, compared with nonusers. These studies[19,20] addressed some confounders at baseline, but limitations included denture use assessment only at baseline and not considering denture use and other relevant confounders, including the number of natural teeth and other health conditions, which may change during the long-term follow-up periods.

To estimate the association between continuous dental prosthesis use and mortality requires an advanced analytic approach because the number of natural teeth during follow-up affects dental prosthesis use and mortality[11–15] and is influenced by previous dental prosthesis use. Inverse probability of treatment weighting and the g-formula (so-called g-methods) are statistical approaches used to address this issue by modeling the exposure or outcome, respectively, providing unbiased estimates for time-varying exposure with treatment-confounder feedback.[21] The research hypothesis was that dental prosthesis use would be associated with reduced risk of all-cause mortality in older adults after considering the time-varying nature of dental prosthesis use and the relevant confounders.

MATERIAL AND METHODS

This prospective cohort study used data from the Japan Gerontological Evaluation Study (JAGES), a cohort study targeting Japanese adults aged ≥65 years without certification for long-term care insurance. In Japan, dental prosthesis treatment is covered by universal health coverage; however, financial barriers have been reported.[22,23] The baseline questionnaire survey was conducted in 2013, and participants were followed up for all-cause mortality until November 2022 according to information from the local municipality registry (median follow-up: 9.2 years). Follow-up questionnaire surveys were conducted in 2016 and 2019 to evaluate time-varying characteristics. This study obtained approval from the ethics committees of Nihon Fukushi University (13–14), Chiba University (No. 2493 and 3442), National Center for Geriatrics and Gerontology (No. 992 and 1274–2), Japan Agency for Gerontological Evaluation Study (No. 2019–01), and Tokyo Medical and Dental University (No. D2022–040).

Supplemental Figure 1, available online, shows the flowchart for the study participants. The JAGES survey targeted those without long-term care insurance certification; thus, some individuals were ineligible for the JAGES follow-up questionnaire surveys, although they were not deceased. The follow-up questionnaires were not distributed to them; however, they were included in the analysis because they answered the baseline questionnaire and their information on mortality was available. The final analysis included 47 698 respondents; of those, 19.0% died and 2.4% were lost to follow-up, mostly because of relocation.

The outcome of this study was all-cause mortality. The Japanese national tracking system enabled the study to associate most participants with their date of death (follow-up rate: 97.6%). In accordance with the data structure described previously,[24] 3 binary variables were defined using the participant date of death, obtained from the local municipality database, to represent participant survival status in the 2016 survey, the 2019 survey, and at the end of the follow-up.

The exposure variable, dental prosthesis use, was evaluated using the following questions. In 2013, the question was, "Do you wear dentures or bridges (nonremovable dentures) or have dental implants?" with possible response options of "No," "Yes, in the upper jaw," "Yes, in the lower jaw," and "Yes, in both jaws." In 2016 and 2019, the question was, "Do you wear dentures or bridges (nonremovable dentures) or have dental implants?" with possible response options of "No," "Dentures," "Dental bridges (nonremovable dentures)," and "Dental implants." The variables were dichotomized, indicating dental prosthesis use.

Covariates were selected following the disjunctive cause criterion.[25] Sex and years of education were evaluated at baseline. Time-varying variables were assessed in 2013, 2016, and 2019, including age, the number of natural teeth, marital status, equivalent income, self-rated health, having limitations in the instrumental activities of daily living,[26] having subjective cognitive complaints,[27] depressive symptoms,[28] diabetes, a stroke, and a history of falls in the past year, and current smoking, walking time, body mass index, and social participation.[7,29]

Supplemental Figure 2, available online, illustrates the directed acyclic graph used for the analysis. The analyses primarily aimed to estimate the difference in population survival probability between counterfactual scenarios, specifically when everyone consistently used dental prostheses and when no one ever used dental prostheses during the follow-up.

First, logistic regression was fitted to investigate the association of dental prosthesis use in each survey wave as a single time point exposure with all-cause mortality. Three models were constructed for each: a crude model, a model controlling for the number of teeth, age, and sex (controlling model), and a model further controlling for years of education, marital status, equivalent income, self-rated health, having limitation in instrumental activities of daily living, having subjective cognitive complaints, depressive symptoms, diabetes, a stroke, and a history of falls in the past year, and current smoking, walking time, body mass index, and social participation (further controlling model). Loss-to-follow-up was considered by the stabilized inverse probability of the censoring weighting approach, where the loss to follow-up was predicted by the exposure, time-fixed, and time-varying covariates.

Second, the target minimum loss-based estimation (TMLE) was performed to estimate the survival probability following different counterfactual scenarios. TMLE is a doubly robust estimator that models both outcome and exposure and provides unbiased estimates when either model is correctly specified.[30] The SuperLearner,[31] an ensemble machine learning algorithm, was used with generalized linear models and neural networks as candidate algorithms to reduce model misspecification risk. The default settings of the package were used for each algorithm, and the models were developed using 5-fold cross-validation. The model estimated survival probability following the trajectory of exposure as observed (natural course) and 2 counterfactual scenarios with deterministic intervention strategies: when everyone consistently used dental prostheses and when no one ever used dental prostheses. The analysis included all participants, regardless of the number of remaining teeth, considering that 87.9% of older individuals in Japan had lost ≥1 natural tooth.[32] Stratified analyses were conducted for those with <20 natural teeth and those with <10 natural teeth. Packages (lmtp and SuperLearner; The R Project for Statistical Computing) were used for these analyses.[24,31] Moreover, E-values were calculated to assess whether unmeasured confounders were likely to fully explain the observed association.

Missing data on variables were imputed by using multiple imputations with chained equations under the missing-at-random (MAR) assumption. Sensitivity analysis under the missing-not-at-random (MNAR) assumption was performed using the delta method.[33,34] Four scenarios with varying magnitudes of MNAR component were tested: delta values of −0.08, −0.04, +0.04, and +0.08. These corresponded to MNAR assumptions that the probability of dental prosthesis use in the imputed data differs from that in the observed data by −2, −1, +1, and +2% points, respectively. Missing information for each variable among respondents ranged from 1.4% for self-rated health and falling experience in 2013 to 29.2% for social participation in 2016 (Supplemental Table 1, available online). Ten pseudo-complete datasets were created, and the Rubin formula was used to combine the estimates. Supplemental Figure 3, available online, shows that the demographic characteristics of the imputed samples were similar to those of the response samples compared with those of the complete cases, thereby reducing selection bias. A software program (R version 4.4.3; The R Project for Statistical Computing) was used for TMLE analysis, whereas a different statistical software program (Stata/MP version 18; StataCorp LLC) was used for other analyses.

RESULTS

Table 1 describes the baseline demographic characteristics and all-cause mortality of the participants. Dental prostheses were used by 24 877 individuals (55.8% of those who responded to the question). Individuals using dental prostheses appeared to be older, had fewer teeth, were unmarried, and had poor health conditions. Of the followed participants, 19.0% died. The mortality rate was higher for those using dental prostheses (20.3%) than those not using them (16.4%). Supplemental Tables 2 and 3, available online, report that the proportion of dental prosthesis users was 66.8% and 68.4% in the 2016 and 2019 follow-up surveys, respectively and that covariate distributions by dental prosthesis use were similar across the survey waves.

Table 2 depicts the probability of dental prosthesis use in consecutive survey waves based on dental prosthesis use or nonuse. Among those not using dental prostheses in 2013, 37.8% started using dental prostheses between 2013 and 2016, whereas 8.3% of dental prosthesis users in 2013 discontinued their use between 2013 and 2016. Similarly, among those not using dental prostheses in 2016, 22.6% started using dental prostheses between 2016 and 2019, whereas 7.4% of dental

Table 1. Baseline demographic characteristics and all-cause mortality by dental prosthesis use (n=47 698)

		Dental Prosthesis Use		
	Overall 47698	**No** n=19741 (44.2%)[a]	**Yes** n=24877 (55.8%)[a]	**Missing** n=3080
	n (%)[a]	n (%)[a]	n (%)[a]	n (%)[a]
Survival status at the end of follow-up				
Alive	37487 (78.6%)	16053 (81.3%)	19228 (77.3%)	2206 (71.6%)
Died	9083 (19.0%)	3239 (16.4%)	5061 (20.3%)	783 (25.4%)
Lost to follow	1128 (2.4%)	449 (2.3%)	588 (2.4%)	91 (3.0%)
Number of natural teeth				
≥20	23861 (51.4%)	14277 (73.2%)	8411 (34.7%)	1173 (43.5%)
10–19	10027 (21.6%)	2741 (14.1%)	6735 (27.8%)	551 (20.4%)
1–9	7939 (17.1%)	1552 (8.0%)	5927 (24.5%)	460 (17.1%)
0	4602 (9.9%)	933 (4.8%)	3158 (13.0%)	511 (19.0%)
Missing	1269	238	646	385
Age (years)[b]	73.6 (6.1)	72.5 (5.5)	74.0 (6.3)	76.5 (6.2)
Sex				
Male	22259 (46.7%)	9369 (47.5%)	11955 (48.1%)	935 (30.4%)
Female	25439 (53.3%)	10372 (52.5%)	12922 (51.9%)	2145 (69.6%)
Years of education				
≤9	20213 (43.2%)	8048 (41.4%)	10307 (42.2%)	1858 (63.5%)
10–12	17897 (38.3%)	7597 (39.1%)	9497 (38.9%)	803 (27.5%)
≥13	8666 (18.5%)	3772 (19.4%)	4631 (19.0%)	263 (9.0%)
Missing	922	324	442	156
Marital status				
Not having partner	12179 (26.1%)	4522 (23.3%)	6602 (27.0%)	1055 (37.2%)
Having partner	34448 (73.9%)	14860 (76.7%)	17809 (73.0%)	1779 (62.8%)
Missing	1071	359	466	246
Equivalent income (M JPY)[b]	2.3 (1.5)	2.3 (1.5)	2.3 (1.5)	1.7 (1.2)
Missing	9094	3467	4488	1139
Self-rated health				
Very good/good	39243 (83.4%)	16586 (84.9%)	20275 (82.6%)	2382 (80.1%)
Poor/very poor	7805 (16.6%)	2939 (15.1%)	4273 (17.4%)	593 (19.9%)
Missing	650	216	329	105
Functional limitation[c]				
No	19509 (43.7%)	8460 (45.3%)	10051 (43.0%)	998 (39.1%)
Yes	25084 (56.3%)	10229 (54.7%)	13302 (57.0%)	1553 (60.9%)
Missing	3105	1052	1524	529
Subjective cognitive complaints[d]				
No	30389 (65.2%)	13019 (67.3%)	15645 (64.3%)	1725 (59.3%)
Yes	16202 (34.8%)	6328 (32.7%)	8692 (35.7%)	1182 (40.7%)
Missing	1107	394	540	173
Depressive symptoms[e]				
No	29,847 (74.9%)	12,784 (75.9%)	15,591 (74.4%)	1472 (71.0%)
Yes	10024 (25.1%)	4068 (24.1%)	5356 (25.6%)	600 (29.0%)
Missing	7827	2889	3930	1008
Diabetes				
No	38941 (86.5%)	16227 (87.1%)	20296 (86.0%)	2418 (86.4%)
Yes	6090 (13.5%)	2414 (12.9%)	3297 (14.0%)	379 (13.6%)
Missing	2667	1100	1284	283
Stroke				
No	43614 (96.9%)	18098 (97.1%)	22826 (96.7%)	2690 (96.2%)
Yes	1417 (3.1%)	543 (2.9%)	767 (3.3%)	107 (3.8%)
Missing	2667	1100	1284	283
Falling experience				
No	36530 (77.6%)	15517 (79.5%)	18845 (76.7%)	2168 (72.9%)
Yes	10517 (22.4%)	3998 (20.5%)	5714 (23.3%)	805 (27.1%)
Missing	651	226	318	107
Current smoking				
No	42329 (90.1%)	17649 (90.5%)	21907 (89.3%)	2773 (93.4%)
Yes	4659 (9.9%)	1852 (9.5%)	2612 (10.7%)	195 (6.6%)
Missing	710	240	358	112
Walking time				
≥0.5 h a day	35171 (75.2%)	14710 (75.7%)	18390 (75.2%)	2071 (71.0%)
<0.5 h a day	11627 (24.8%)	4723 (24.3%)	6058 (24.8%)	846 (29.0%)
Missing	900	308	429	163
Body mass index				
Normal or above (≥18.5)	42431 (93.4%)	17802 (93.9%)	22144 (93.2%)	2485 (92.0%)
Underweight (<18.5)	2989 (6.6%)	1149 (6.1%)	1624 (6.8%)	216 (8.0%)
Missing	2278	790	1109	379
Social participation[f]				
<1 time/week	26496 (70.0%)	11114 (69.1%)	13960 (70.1%)	1422 (77.4%)
≥1 time/week	11342 (30.0%)	4974 (30.9%)	5952 (29.9%)	416 (22.6%)
Missing	9860	3653	4965	1242

[a] Percentage calculated, excluding responses with missing information.

[b] Values represent mean and standard deviation.

[c] Assessed with Tokyo Metropolitan Institute of Gerontology Index of Competence.

[d] Assessed with Geriatric Depression Scale 15 score≥5.

[e] Having subjective cognitive complaints≥1.

[f] Participation in any of following group activities: hobby groups, sports clubs, senior citizens' clubs, residence groups, or volunteer groups.

Table 2. Transition of dental prosthesis use[a]

	Dental Prosthesis Use in Next Survey Wave[b]	
	No Row % (95% CI)	Yes Row % (95% CI)
Dental prosthesis use in 2013		
No	62.2 (61.3, 63.0)	37.8 (37.0, 38.7)
Yes	8.3 (7.8, 8.7)	91.7 (91.3, 92.2)
Dental prosthesis use in 2016		
No	77.4 (76.0, 78.8)	22.6 (21.2, 24.0)
Yes	7.4 (6.9, 8.0)	92.6 (92.0, 93.1)

CI, confidence interval.

[a] Changes in dental prosthesis use from 2013 to 2016 (n=46 062 after imputation) and from 2016 to 2019 (n=42 170 after imputation) presented; those who died or lost to follow excluded.

[b] Percentage in 2016 according to dental prosthesis use in 2013 or that in 2019 according to dental prosthesis use in 2016.

prosthesis users in 2016 discontinued their use between 2016 and 2019.

Table 3 shows the association of dental prosthesis use with mortality, as estimated using the logistic regression analysis. The crude mortality incidence for baseline dental prosthesis users and nonusers was 17.3% and 21.3%, respectively. The crude incidence demonstrated that mortality was higher in those using dental prostheses. This association was reversed in the controlling model, controlling for the number of natural teeth, age, and sex. The further controlling model, controlling for all covariates, showed that mortality was lower for those using dental prostheses (odds ratio [OR]=0.91; 95% confidence interval [CI]: 0.86, 0.97). Similar associations were observed for different waves. However, the association for dental prosthesis use in 2019, controlling for all covariates, was not significant (OR=0.92; 95% CI: 0.76, 1.11).

Fig. 1 illustrates the survival probability in the natural course and counterfactual scenarios. As seen in Table 4, the survival probability in the overall population significantly increased by 3.7% points when everyone consistently used dental prostheses compared with when no one ever used dental prostheses (95% CI: 0.3, 7.0). The magnitude of associations was greater in individuals with fewer natural teeth, although it was not statistically significant for those with <10 natural teeth. The E-values for the estimates comparing consistent denture use with nonuse ranged from 1.27 to 1.60. Similar results were observed under the MNAR assumptions, although 2 of the 4 estimates were not statistically significant (Supplemental Table 4, available online).

Table 3. Association between dental prosthesis use at each wave and mortality by end of follow-up

	Mortality[a] % (95% CI)	Crude model OR (95% CI)	Controlling model OR (95% CI)	Further controlling model OR (95% CI)
Dental status in 2013[b]				
Using dental prosthesis				
No	17.3 (16.7,17.8)	Reference	Reference	Reference
Yes	21.3 (20.8,21.8)	1.30 (1.24,1.36)	0.89 (0.84,0.94)	0.91 (0.86,0.97)
Number of natural teeth				
≥20	13.7 (13.3,14.2)	Reference	Reference	Reference
10–19	20.5 (19.7,21.3)	1.62 (1.52,1.72)	1.40 (1.31,1.50)	1.27 (1.18,1.36)
1–9	26.6 (25.7,27.6)	2.28 (2.15,2.43)	1.58 (1.46,1.69)	1.34 (1.24,1.44)
0	34.6 (33.2,36.0)	3.32 (3.09,3.57)	1.76 (1.62,1.91)	1.47 (1.34,1.60)
Dental status in 2016[c]				
Using dental prosthesis				
No	12.4 (11.8,13.0)	Reference	Reference	Reference
Yes	17.7 (17.2,18.1)	1.51 (1.42,1.61)	0.87 (0.80,0.95)	0.89 (0.82,0.97)
Number of natural teeth				
≥20	10.5 (10.1,11.0)	Reference	Reference	Reference
10–19	17.9 (16.9,18.8)	1.85 (1.71,2.00)	1.61 (1.48,1.75)	1.46 (1.34,1.59)
1–9	22.1 (20.9,23.3)	2.42 (2.21,2.64)	1.65 (1.48,1.85)	1.42 (1.27,1.59)
0	26.0 (24.7,27.3)	2.99 (2.76,3.24)	1.60 (1.44,1.77)	1.31 (1.18,1.46)
Dental status in 2019[d]				
Using dental prosthesis				
No	7.2 (6.5,8.0)	Reference	Reference	Reference
Yes	10.0 (9.6,10.4)	1.43 (1.24,1.64)	0.86 (0.71,1.04)	0.92 (0.76,1.11)
Number of natural teeth				
≥20	6.1 (5.7,6.6)	Reference	Reference	Reference
10–19	8.9 (8.3,9.6)	1.50 (1.34,1.69)	1.33 (1.14,1.54)	1.17 (1.00,1.37)
1–9	11.9 (10.9,12.8)	2.06 (1.80,2.37)	1.49 (1.25,1.77)	1.24 (1.04,1.48)
0	16.8 (15.6,18.0)	3.10 (2.75,3.48)	1.73 (1.44,2.09)	1.38 (1.13,1.67)

CI, confidence interval; OR, odds ratio.

Loss-to-follow-up on all-cause mortality considered by inverse probability of censoring weights.

Crude model: Dental prosthesis use and number of remaining teeth separately included in model.

Controlling model: Dental prosthesis use and number of remaining teeth simultaneously included in model, controlling for age and sex.

Further controlling model: Dental prosthesis use and number of remaining teeth simultaneously included in model, controlling for age, sex, years of education, marital status, equivalent income, self-rated health, functional limitation, having subjective cognitive complaints, depression, diabetes, stroke, falling experience in past year, current smoking, walking time, body-mass index, and social participation.

[a] Mortality rate by 2022.

[b] Reporting association of dental prosthesis use and number of natural teeth in 2013 with mortality by 2022 (n=47 269)

[c] Reporting association of dental prosthesis use and number of natural teeth in 2016 with mortality by 2022 (n=45 300)

[d] Reporting association of dental prosthesis use and number of natural teeth in 2019 with mortality by 2022 (n=41 888)

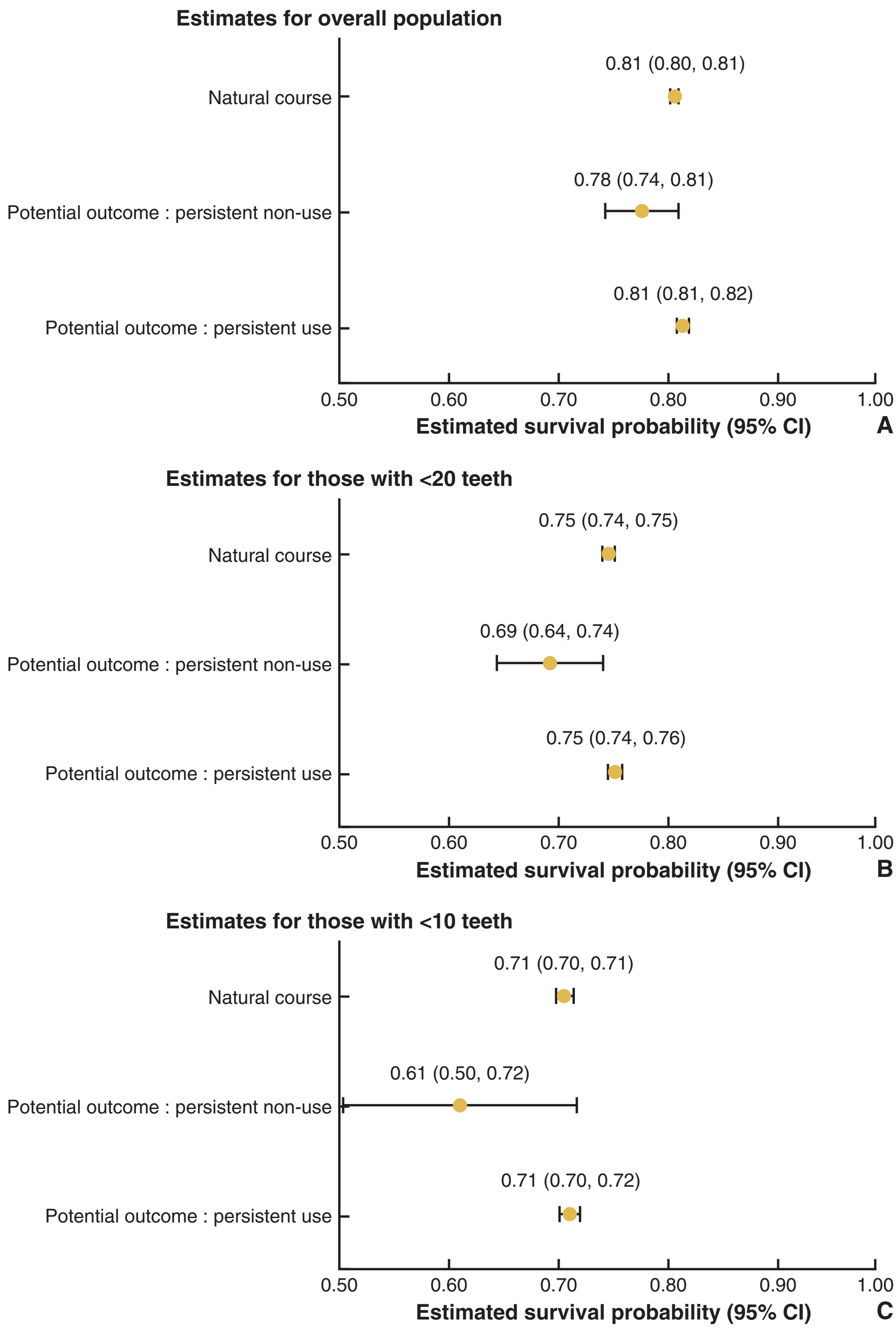

Figure 1. Estimated survival probabilities at end of follow-up by dental prosthesis use. A, Estimates for overall population. B, Estimates for those with <20 teeth. C, Estimates for those with <10 teeth. Natural course: $E[Y^{(A_{13},A_{16},A_{19})}]$; Consistent use: $E[Y^{(1,1,1)}]$; Consistent nonuse: $E[Y^{(0,0,0)}]$; $Y^{(a_{13},a_{16},a_{19})}$ presents outcome (survive at end of follow-up) with exposure $a_t = a$, where *t* indicates survey time point, *a*=1 indicates dental prosthesis use, and 0 indicates nonuse. A_t indicates observed level of exposure.

Table 4. Estimated average treatment effects of consistent dental prosthesis use

	ATE (Percentage Points) Estimate (95% CI)	*P*	E-value
Overall population			
Consistent use vs. status quo (reference)	0.7 (0.3, 1.1)	<.001	1.10
Consistent use vs. consistent nonuse (reference)	3.7 (0.3, 7.0)	.031	1.27
Population with less than 20 remaining teeth at baseline			
Consistent use vs. status quo (reference)	0.6 (0.2, 0.9)	.003	1.09
Consistent use vs. consistent nonuse (reference)	5.9 (1.0, 10.8)	.018	1.39
Population with less than 10 remaining teeth at baseline			
Consistent use vs. status quo (reference)	0.5 (0.1, 1.0)	.025	1.09
Consistent use vs. consistent nonuse (reference)	10.0 (−0.6, 20.6)	.064	1.60

ATE, average treatment effect; CI, confidence interval.

Natural course: $E[Y^{(A_{13},A_{16},A_{19})}]$; Consistent use: $E[Y^{(1,1,1)}]$; Consistent nonuse: $E[Y^{(0,0,0)}]$; $Y^{(a_{13},a_{16},a_{19})}$ presents outcome (that is, survive at end of follow-up) with exposure $a_t = a$, where t indicates survey time point and a=1 indicates dental prosthesis use, and 0 indicates nonuse. A_t indicates observed level of exposure.

DISCUSSION

The results of this study supported the research hypothesis that dental prosthesis use is associated with a reduced risk of all-cause mortality in older adults after accounting for the time-varying nature of dental prosthesis use and relevant confounders. The effect size compared with the never-use scenario was 3.7% points for the overall population, 5.9% points for those with <20 natural teeth, and 10.0% points for those with <10 natural teeth, although it was not statistically significant for those with <10 natural teeth (P>.05).

The authors are unaware of a previous study that investigated the association of dental prosthesis use assessed at multiple time points with all-cause mortality. The large-scale longitudinal data with repeated measurements enabled the study to model the dental prosthesis use trajectories and their association with the mortality of older adults.

Limitations of this study included that the exposure and covariates were evaluated using self-reported questionnaire surveys. The definition of exposure variable, using or not using any dental prosthesis, did not include information on the types or quality of dental prostheses. Self-report classifications of dental prostheses, such as removable dentures, nonremovable dentures, and dental implants, were available in the 2016 and 2019 surveys, but the information was not incorporated because of its nonavailability in the baseline survey and potential misclassification associated with self-reporting. Future studies involving clinical dental examinations are important for evaluating the robustness of the findings.

Information on follow-up surveys was lacking because of noneligibility or nonresponse. Multiple imputations were performed, and characteristics of the analysis sample were confirmed as similar to those of response participants, but selection bias may have influenced the estimates.

While a rich set of time-fixed and time-varying covariates were controlled for, unmeasured confounders such as oral or overall health, socioeconomic status, or access to dental care may be present. The observed association is fully explained if the unmeasured confounding factor is associated with both exposure and outcome, with the magnitude greater than the E-values after controlling for the same set of covariates in this study's analysis.

The transportability of the findings to the non-Japanese population is limited. Further research in other countries is required to identify whether similar findings might be observed in other populations.

Although the association was statistically significant, its magnitude may be clinically modest. The estimated percentage point differences may be challenging to compare directly with previous studies that reported hazard ratios.

Different reasons for loss to follow-up were not considered when accounting for censoring. Acknowledging these limitations, the present study provides important evidence in this area, where randomized controlled trials of dental prostheses with long-term follow-up are unethical and infeasible.

Dental prostheses have been reported to mitigate the effect of tooth loss on all-cause mortality.[11,18] However, these studies were less conclusive because of methodological limitations, including small sample sizes and inadequate confounding adjustment. Two recent studies among adults in the United States[19,20] considered confounding factors and revealed that dental prosthesis use can mitigate the effect of tooth loss on mortality. Sabbah et al[19] used data on edentulous adults from the Third National Health and Nutritional Examination Survey. They demonstrated that those who used complete dentures exhibited a 21% lower risk of mortality during the 25-year follow-up compared with propensity score-matched edentulous nondenture users. Similarly, Bashir and Bernabé[20] revealed that removable partial dentures were associated with a 26% increase in survival time compared with nonusers among individuals with <20 natural teeth. The present study considered the time-varying nature of dental prosthesis use and relevant confoundings and added to the literature that the continuous use of dental prostheses was associated with a reduction in all-cause mortality in older adults.

Some mechanisms have been proposed to explain the association between dental prosthesis use and all-cause mortality. Dental prosthesis use with dietary advice reportedly improves nutritional status,[16,17] although whether the present study participants had dietary advice when they were provided with dental prostheses is unclear. A randomized controlled trial in Japan[16] reported increased protein intake among edentulous older adults who received removable complete dentures with simple dietary advice compared with the control group. A systematic review summarized previous studies and revealed supportive evidence, but large-scale theory-based intervention studies are warranted.[17]

Dental prosthesis use may reduce psychological stress related to tooth loss, such as embarrassment and unstable feelings, thereby increasing social interaction. A study revealed that dental prosthesis use mitigated the association of having fewer natural teeth with social isolation for 6 years.[8] However, these studies evaluated dental prosthesis use at a single point; thus, further research is required to disentangle the mechanisms of the long-term use of dental prostheses to reduce mortality risk.

The findings of this study have important implications for public health. In Japan, 66% of adults lost ≥1 tooth in 2020.[32] Dental prostheses can mitigate the impact on mortality among those with tooth loss. Further, social gradients in dental prosthesis use have been reported even in countries with universal health coverage.[22,23] Reducing barriers to dental care to ensure the continuous use of dental prostheses may reduce mortality among older people with tooth loss.

CONCLUSIONS

Based on the findings of this prospective cohort study, the following conclusions were drawn:

1. Consistent dental prosthesis use was associated with increased survival probability for 9 years in Japanese older adults.
2. Further studies are warranted to determine the underlying mechanisms and confirm the results in other populations.

DATA AVAILABILITY STATEMENT

Access to JAGES data is restricted due to ethical and legal considerations involving sensitive human participant information. Data use is available upon reasonable request by contacting the JAGES data management committee at dataadmin.ml@jages.net.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

The authors used ChatGPT-4o only to correct grammar and improve readability in the draft; all content was subsequently reviewed and edited by the authors, who take full responsibility for the publication.

APPENDIX A. SUPPORTING INFORMATION

Supplemental data associated with this article can be found in the online version at doi:10.1016/j.prosdent.2025.05.007.

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