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Baseline dentition and incident dementia in Chinese very-old adults: denture use, functional limitation, CLHLS 2008-2018

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Institutional review board statement

The Chinese Longitudinal Healthy Longevity Survey received approval from the Ethics
Committee of Peking University, IRB00001052-13074. Written informed consent was
obtained from all participants or their legal representatives. This study is a secondary
analysis of de-identified CLHLS data.

Data availability

Data from the Chinese Longitudinal Healthy Longevity Survey used in this study are
publicly available through the Peking University Open Research Data Platform. Access

is provided to registered users under the platform's data use terms. The dataset is archived with the persistent identifier doi:10.18170/DVN/WBO7LK

Declaration of Conflict of interest

The authors declare no conflict of interests.

ABSTRACT

Background: Tooth loss is common in very old age, yet evidence is mixed on whether baseline tooth count independently predicts incident dementia, particularly when oral rehabilitation and overall functional status are considered.

Objective: To examine whether baseline natural tooth count is associated with incident dementia in very old adults, and whether denture use and activities of daily living (ADL) limitation provide additional prognostic information.

Methods: We analysed 7,941 dementia-free participants aged ≥ 65 years from the Chinese Longitudinal Healthy Longevity Survey (2008–2018). Baseline tooth count was categorised as 0, 1–9, 10–19, and ≥ 20 teeth; denture use was recorded. Multivariable discrete-time complementary log-log models with cluster-robust standard errors were fitted, adjusting for sociodemographic and lifestyle factors and categorical ADL limitation. Prespecified robustness checks included restricted cubic splines, models without ADL adjustment, use of continuous ADL score, and a landmark analysis starting follow-up in 2011.

Results: Baseline tooth count was not associated with incident dementia. Compared with ≥ 20 teeth, hazard ratios were 1.12 (95% CI 0.79–1.59) for 0 teeth, 1.03 (0.75–1.42) for 1–9 teeth, and 0.89 (0.63–1.26) for 10–19 teeth; spline analyses showed no overall association ($P = 0.737$). Denture use was associated with a lower dementia hazard (HR 0.78, 95% CI 0.61–0.98). ADL limitation showed the strongest gradient, with ≥ 2 limitations as the reference category: HR 0.39 (0.28–0.53) for 0 limitations and 0.63 (0.41–0.95) for 1 limitation. Findings were robust across sensitivity analyses.

Conclusion: In this Chinese cohort enriched for the oldest-old, baseline tooth count alone was not independently associated with incident dementia, whereas denture use and functional limitation provided important prognostic information.

Clinical significance: Oral rehabilitation with dentures and functional assessment may be prioritised alongside tooth count for dementia risk stratification in very old adults.

Keywords: Dementia; Denture use; Tooth count; Activities of daily living; Oral rehabilitation; CLHLS

1. Introduction

Dementia is a leading cause of disability and dependency in older adults, and its societal impact is rising as populations age and survival improves.¹ Global projections indicate that the number of people living with dementia will increase substantially in coming decades, reinforcing the importance of prevention, early detection, and risk stratification across diverse settings.² These priorities are especially pressing in late life, when multiple chronic conditions and functional vulnerability are common and when identifying practical, scalable correlates of dementia risk becomes clinically relevant.

Oral health is one such domain because oral diseases are common, accumulate across the life course, and often remain undertreated in ageing societies.³ Global burden analyses show that tooth loss and other oral conditions contribute meaningfully to years lived with disability and reflect large inequalities in access to preventive and restorative care.⁴ In China, tooth loss and edentulism are frequent among older adults, while prosthodontic rehabilitation does not always align with need, leaving substantial variation in oral function despite similar levels of tooth loss.⁵ This raises a pragmatic question in geriatric epidemiology. Can a simple baseline marker such as natural tooth count help identify older adults at higher risk of incident dementia, and does oral rehabilitation carry information beyond tooth count?

A growing observational literature has reported associations between tooth loss, periodontal disease, and later cognitive impairment or dementia, with meta-analytic evidence suggesting a graded relationship between fewer teeth and higher dementia risk.⁶ Longitudinal syntheses also support associations between periodontal health and subsequent cognitive decline, consistent with inflammatory and vascular pathways that may connect oral disease to brain health.⁷ Large prospective studies have likewise found that poor oral health markers are associated with incident dementia, although estimates vary with exposure definitions and outcome ascertainment.⁸ Interpretation remains challenging because oral health is intertwined with healthcare access, nutrition, comorbidity accumulation, and functional decline over time, which can introduce time-varying confounding and make a single baseline measure an incomplete summary of long-term oral experience.⁹ These issues may be particularly consequential in the oldest-old, where distal exposures can be harder to detect against a background of multiple competing risks and rapid health changes.

Another possibility is that oral function and rehabilitation matter more than tooth count alone. Systematic evidence linking measured masticatory performance with cognitive status supports the relevance of functional oral capacity as an intermediate phenotype.¹⁰ Neurophysiologic synthesis has also suggested that prosthodontic rehabilitation can be accompanied by changes in brain activity, providing plausibility for pathways related to sensory-motor stimulation, diet, and social participation.¹¹ In China, longitudinal cohort evidence has reported slower cognitive decline among older adults with partial tooth loss who used dentures, raising the hypothesis that rehabilitation may mitigate downstream consequences of tooth loss.¹² At the same time, clinical intervention evidence remains heterogeneous, and recent reviews emphasize variation in interventions and cognitive endpoints, so observational findings should not be treated as causal proof.¹³ Given high mortality in very old cohorts, we interpret these

associations primarily as prognostic signals and note that death and attrition may influence observed incidence.¹⁴

Using the Chinese Longitudinal Healthy Longevity Survey, we examined whether baseline natural tooth count was associated with incident dementia during follow up from 2008 to 2018.¹⁵ We categorized tooth count into clinically interpretable groups, incorporated denture use as an indicator of oral rehabilitation, and accounted for functional status using activities of daily living. We applied a discrete-time survival framework suited to dementia onset observed only at survey waves, and we conducted prespecified robustness checks, including nonlinearity assessment and a landmark analysis excluding early events, to reduce sensitivity to reverse causation. Our aim was to clarify whether baseline tooth count provides independent information on dementia risk in very old adults, and to assess whether denture use and functional limitation help explain heterogeneity in observed associations within this population.

2. Methods

2.1 Study design and data source

We conducted a longitudinal cohort analysis using data from the Chinese Longitudinal Healthy Longevity Survey, a nationwide study of older adults with repeated assessments and long follow-up. The analytic baseline was the 2008 wave, with subsequent follow-up across 2008–2011, 2011–2014, and 2014–2018 (Figure 1).

2.2 Study population

Participant selection is summarised in Figure 1. In brief, 16,954 individuals were assessed at baseline. After restricting to those aged 65 years or older and excluding prevalent dementia and missing or unknown dementia status at baseline, we retained 15,908 participants with baseline tooth count available. Among them, dementia status during follow-up could be ascertained for 7,941 participants, who comprised the final analytical cohort.

2.3 Exposure assessment

The exposure of interest was baseline natural tooth count. Tooth count was categorized as 0, 1–9, 10–19, and ≥ 20 teeth to reflect clinically meaningful gradients of tooth retention and to allow robust comparisons across distribution tails. Denture use (yes/no) was treated as a covariate representing oral rehabilitation status.

2.4 Outcome definition

The primary outcome was incident dementia during follow-up, defined as newly identified dementia at any follow-up wave among those free of dementia at baseline.¹⁶ Because the exact onset date is not observed between survey waves, events were treated as occurring within discrete follow-up intervals.

2.5 Functional status assessment

Activities of daily living were assessed using six standard ADL items. Functional limitation was operationalized in two ways. First, we created a categorical ADL limitation variable based on the number of limitations (0, 1, or ≥ 2), with ≥ 2 representing the most impaired category. Second, for sensitivity analysis, we modeled the ADL score as a continuous measure. Higher ADL scores indicate greater functional limitation, and item coding is shown in Table S3 footnote.

2.6 Covariates

We adjusted for covariates selected a priori based on clinical plausibility and prior cohort literature, including age, sex, education, marital status, residence (urban vs rural), current smoking, current drinking, regular exercise, sleep duration (<7 h, 7–9 h, >9 h), body mass index category (<18.5, 18.5–23.9, 24.0–27.9, ≥ 28.0 kg/m², and missing), denture use, and follow-up interval indicators. Missingness for selected covariates was handled using missing-indicator categories where applicable; for sparse categories that yielded unstable estimates, corresponding coefficients were retained in the model but are not presented; details are provided in Supplementary Table S4.¹⁷

2.7 Statistical analysis

2.7.1 Primary association model

We modeled incident dementia using a discrete-time survival framework appropriate for interval-censored event times, implemented via a complementary log-log link over person-interval data. This approach estimates hazard ratios that approximate relative hazards across intervals under standard discrete-time assumptions.¹⁸ Standard errors were clustered at the participant level to account for repeated intervals per person, using a robust sandwich estimator recommended for clustered longitudinal inference.

2.7.2 Sequential models accounting for functional limitation using activities of daily living

To examine whether adjustment for functional limitation materially changes the tooth count-dementia association, we compared a model without ADL covariates (Table S2) with a model additionally adjusted for categorical ADL limitation (Table 2). We also described the cross-sectional association between baseline tooth count and ADL score using linear regression (Table S1). These sequential models were used to aid interpretation rather than to support a formal mediation analysis, because ADL limitation may reflect early manifestations along the dementia continuum. The conceptual framework is shown in Figure 2.

2.7.3 Sensitivity analyses

We performed three prespecified robustness checks. First, we replaced categorical ADL limitation with continuous ADL score (Table S3). Second, we evaluated nonlinearity for continuous tooth count using restricted cubic splines (Figure S1), testing both the overall association and the nonlinearity component. Third, to reduce reverse causation from subclinical cognitive decline affecting oral health, we conducted a landmark analysis excluding dementia onset during 2008–2011 and initiating follow-up at 2011 (Table S4), a strategy commonly used to address early-event bias.

2.7.4 Prespecified scope and subgroup analyses

Our prespecified objective was to estimate the overall association and conduct robustness checks. We did not perform exploratory subgroup analyses to avoid multiple comparisons and unstable stratum-specific estimates driven by sparse events after stratification. All analyses were two-sided, and statistical significance was evaluated at the 0.05 level.

3. Results

3.1 Participant characteristics

The final cohort included 7,941 older adults (Table 1). Baseline natural tooth count followed a clear social and clinical gradient. Participants with fewer teeth tended to be older, more often female, had lower education, and reported functional limitation more frequently (all $P \leq 0.028$). Lifestyle patterns also differed, with higher prevalences of smoking and alcohol drinking among those with ≥ 20 teeth and lower prevalence of regular exercise among those with fewer teeth. Participant selection and exclusions are shown in Figure 1.

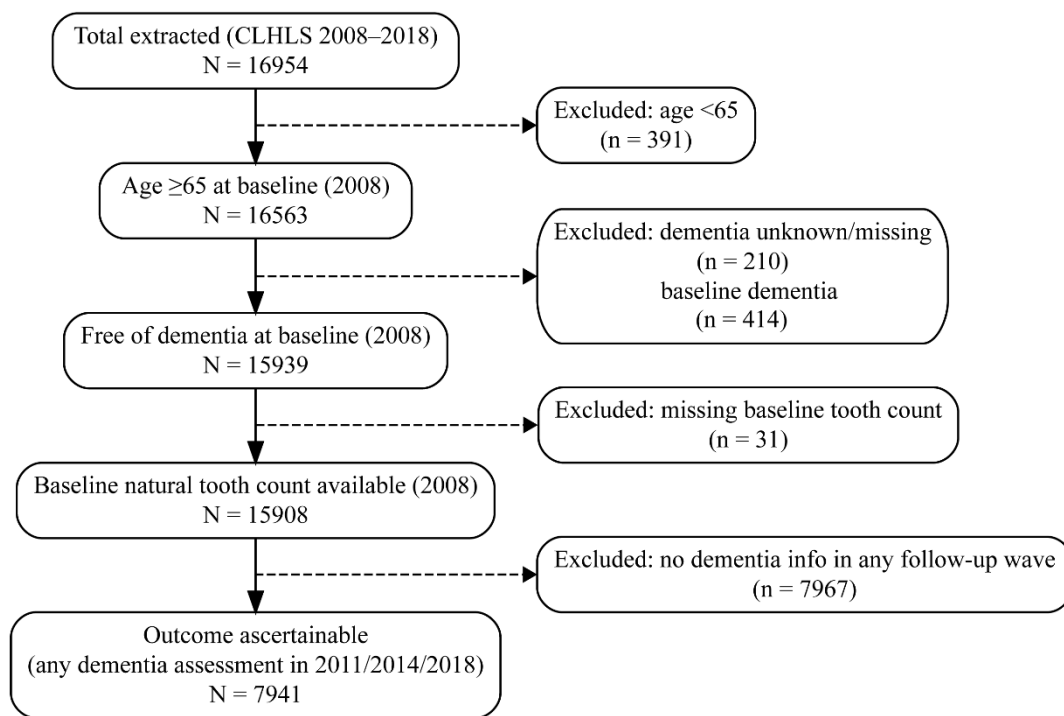


Figure 1. Flow diagram of participant selection from the CLHLS 2008–2018 waves.

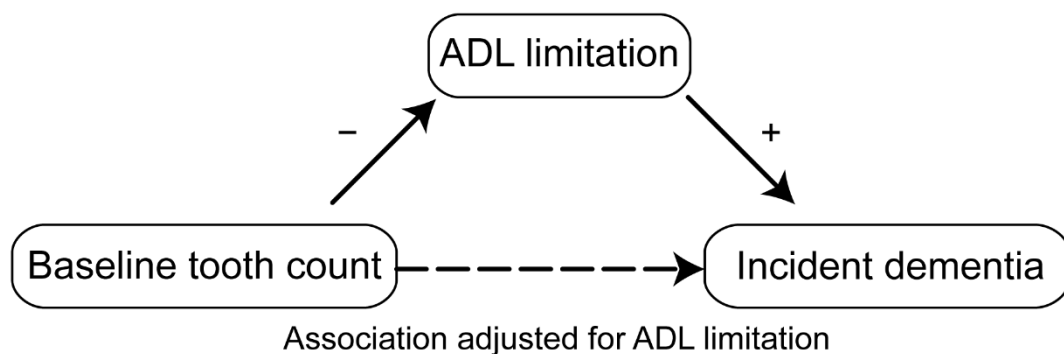


Figure 2. Conceptual framework motivating sequential models with and without ADL limitation. Solid arrows indicate hypothesised associations; the dashed arrow denotes the tooth count-dementia association estimated in models adjusting for ADL limitation.

Table 1. Baseline characteristics of the analytical cohort overall and by baseline natural tooth count categories.

Characteristic	Overall (N = 7,941)	Baseline number of natural teeth				p-value
		0 teeth (N = 2,341)	1–9 teeth (N = 2,296)	10–19 teeth (N = 1,491)	≥20 teeth (N = 1,813)	
Age, years	82 (73, 91)	89 (96)	(81, 92)	86 (79, 92)	79 (72, 86)	72 (68, 80) <0.001
Sex						<0.001
Female	4,343 (55%)	1,478 (63%)	1,322 (58%)	771 (52%)	772 (43%)	
Male	3,598 (45%)	863 (37%)	974 (42%)	720 (48%)	1,041 (57%)	
Education, years						<0.001
≥7	919 (12%)	168 (7.2%)	181 (7.9%)	187 (13%)	383 (21%)	
0	4,509 (57%)	1,584 (68%)	1,489 (65%)	772 (52%)	664 (37%)	
1–6	2,509 (32%)	589 (25%)	623 (27%)	532 (36%)	765 (42%)	
Missing	4 (<0.1%)	0 (0%)	3 (0.1%)	0 (0%)	1 (<0.1%)	
Marital status						<0.001
Married	3,269 (41%)	659 (28%)	727 (32%)	700 (47%)	1,183 (65%)	
Not married	4,672 (59%)	1,682 (72%)	1,569 (68%)	791 (53%)	630 (35%)	
Residence						0.028
Urban	3,050 (38%)	890 (38%)	838 (36%)	578 (39%)	744 (41%)	
Rural	4,891 (62%)	1,451 (62%)	1,458 (64%)	913 (61%)	1,069 (59%)	
Current smoking						<0.001
No	6,326 (80%)	1,915 (82%)	1,869 (81%)	1,217 (82%)	1,325 (73%)	
Yes	1,615 (20%)	426 (18%)	427 (19%)	274 (18%)	488 (27%)	

Characteristic	Overall (N = 7,941)	Baseline number of natural teeth				<i>p</i> -value
		0 teeth (N = 2,341)	1–9 teeth (N = 2,296)	10–19 teeth (N = 1,491)	≥20 teeth (N = 1,813)	
Current alcohol drinking						<0.001
No	6,371 (80%)	1,934 (83%)	1,882 (82%)	1,187 (80%)	1,368 (75%)	
Yes	1,570 (20%)	407 (17%)	414 (18%)	304 (20%)	445 (25%)	
Regular exercise						<0.001
No	5,302 (67%)	1,661 (71%)	1,606 (70%)	982 (66%)	1,053 (58%)	
Yes	2,639 (33%)	680 (29%)	690 (30%)	509 (34%)	760 (42%)	
Sleep duration						<0.001
<7 h	2,095 (26%)	593 (25%)	661 (29%)	377 (25%)	464 (26%)	
>9 h	1,944 (24%)	711 (30%)	606 (26%)	300 (20%)	327 (18%)	
7–9 h	3,902 (49%)	1,037 (44%)	1,029 (45%)	814 (55%)	1,022 (56%)	
ADL limitations						<0.001
0	7,162 (90%)	1,942 (83%)	2,053 (89%)	1,416 (95%)	1,751 (97%)	
1	399 (5.0%)	193 (8.2%)	128 (5.6%)	42 (2.8%)	36 (2.0%)	
≥2	380 (4.8%)	206 (8.8%)	115 (5.0%)	33 (2.2%)	26 (1.4%)	
Denture use						<0.001
No	5,461 (69%)	1,049 (45%)	1,719 (75%)	1,152 (77%)	1,541 (85%)	
Yes	2,480 (31%)	1,292 (55%)	577 (25%)	339 (23%)	272 (15%)	
Body mass index, kg/m ²						<0.001
<18.5	2,170 (27%)	769 (33%)	746 (32%)	353 (24%)	302 (17%)	
≥28	249 (3.1%)	72 (3.1%)	45 (2.0%)	44 (3.0%)	88 (4.9%)	

Characteristic	Overall (N = 7,941)	Baseline number of natural teeth				p-value
		0 teeth (N = 2,341)	1–9 teeth (N = 2,296)	10–19 teeth (N = 1,491)	≥20 teeth (N = 1,813)	
18.5–23.9	4,385 (55%)	1,216 (52%)	1,248 (54%)	876 (59%)	1,045 (58%)	
24.0–27.9	1,046 (13%)	232 (9.9%)	236 (10%)	208 (14%)	370 (20%)	
Missing	91 (1.1%)	52 (2.2%)	21 (0.9%)	10 (0.7%)	8 (0.4%)	

Values are median (Q1, Q3) for continuous variables and n (%) for categorical variables. *P* values were calculated using the Kruskal–Wallis rank-sum test for continuous variables and the Pearson χ^2 test for categorical variables. Natural tooth count was categorized as 0, 1–9, 10–19, and ≥20 teeth. ADL limitation categories represent the number of limitations (0, 1, or ≥2). BMI categories were defined as <18.5, 18.5–23.9, 24.0–27.9, and ≥28.0 kg/m²; a Missing category was retained where applicable.

3.2 Baseline tooth count and incident dementia

In the primary adjusted discrete-time model that included categorical ADL limitation, baseline tooth count was not associated with incident dementia. Relative to participants with ≥20 teeth, the hazard ratio was 1.12 for 0 teeth, 1.03 for 1–9 teeth, and 0.89 for 10–19 teeth, with all confidence intervals spanning 1 (Table 2). The restricted cubic spline analysis was consistent with these findings, showing no evidence of an overall association (*P* = 0.737) or nonlinearity (*P* = 0.638) across the continuous tooth-count range (Figure S1).

Several covariates showed clearer gradients. Dementia hazard increased with age. Denture use was inversely associated with incident dementia after multivariable adjustment (Table 2). Functional status was strongly associated with incident dementia; compared with participants with ≥2 ADL limitations, those with no limitation and those with one limitation had substantially lower hazards.

Table 2. Association between baseline natural tooth count and incident dementia

Variable	HR (95% CI)	<i>P</i> value
Baseline natural tooth count (ref: ≥20 teeth)		
0 teeth	1.12 (0.79–1.59)	0.519
1–9 teeth	1.03 (0.75–1.42)	0.848
10–19 teeth	0.89 (0.63–1.26)	0.524
Time period (ref: 2008–2011)		
2011–2014	1.10 (0.89–1.36)	0.390
2014–2018	1.19 (0.86–1.64)	0.298
Age (per 1-year increase)	1.04 (1.03–1.06)	<0.001
Sex (ref: Female)		
Male	0.82 (0.62–1.07)	0.142
Education (ref: ≥7 years)		
0 years	0.77 (0.53–1.13)	0.181

Variable	HR (95% CI)	P value
1–6 years	0.79 (0.56–1.14)	0.209
Marital status (ref: Married)		
Not married	1.11 (0.85–1.44)	0.448
Residence (ref: Urban)		
Rural	0.97 (0.79–1.18)	0.752
Current smoking (Yes vs No)	0.93 (0.68–1.25)	0.619
Current drinking (Yes vs No)	0.90 (0.67–1.19)	0.447
Regular exercise (Yes vs No)	0.82 (0.66–1.03)	0.092
Sleep duration (ref: <7 h)		
7–9 h	0.80 (0.64–1.01)	0.064
>9 h	1.02 (0.79–1.30)	0.904
ADL limitation (ref: ≥2)		
ADL limitations = 0	0.39 (0.28–0.53)	<0.001
ADL limitations = 1	0.63 (0.41–0.95)	0.028
Denture use (Yes vs No)	0.78 (0.61–0.98)	0.035
BMI (ref: <18.5 kg/m²)		
18.5–23.9 kg/m ²	1.09 (0.87–1.36)	0.447
24.0–27.9 kg/m ²	1.27 (0.92–1.76)	0.150
≥28.0 kg/m ²	1.58 (0.93–2.69)	0.089
Missing	0.63 (0.28–1.43)	0.267

Discrete-time complementary log-log model with cluster-robust standard errors by participant (id). Covariates include follow-up interval, demographics, socioeconomic factors, lifestyle, sleep, oral health, BMI, and categorical ADL limitation.

3.3 Tooth count and functional limitation

In the linear model for ADL score, baseline tooth count was associated with only small differences in functional status. Compared with ≥20 teeth, 0 teeth was associated with a slightly higher ADL score of borderline significance ($\beta = 0.06$; 95% CI, -0.00 to 0.12 ; $P = 0.052$), whereas 1–9 teeth and 10–19 teeth were not clearly different. Several covariates related to ADL score in expected directions, including older age and rural residence, and regular exercise was associated with a lower ADL score (Table S1).

3.4 Robustness checks

Findings were consistent across prespecified sensitivity analyses. When ADL covariates were excluded, tooth-count estimates remained close to the null (Table S2). When categorical ADL limitation was replaced by continuous ADL score, tooth-count estimates again showed no clear association, whereas ADL score was strongly associated with higher dementia hazard (Table S3). In the landmark analysis excluding dementia onset during 2008–2011 and initiating follow-up at 2011, baseline tooth count remained unassociated with incident dementia, and the protective pattern for better ADL status persisted (Table S4). The education-missing indicator was included in the landmark model but not reported because estimation was unstable under sparse data conditions, as noted in Table S4.

Taken together, the results were consistent across models. Baseline tooth count showed little association with incident dementia, whereas functional limitation was strongly associated with dementia risk. Denture use was associated with a lower dementia hazard, and tooth count was only weakly related to ADL status (Tables 2 and S1–S4).

Discussion

Accumulating observational evidence has linked tooth loss and other indicators of poor oral health with subsequent cognitive impairment and dementia in later life.⁶ Periodontal disease has also been associated with dementia risk in systematic syntheses, supporting an inflammatory and vascular plausibility for oral-brain connections⁷. Large population resources further suggest that oral health markers may correlate with incident dementia and neuroimaging signatures, although effect sizes vary across definitions of exposure and outcome⁸. Prospective cohort data such as the Hisayama Study have reported higher dementia risk with fewer remaining teeth, underscoring why tooth retention has been viewed as a potentially informative marker in ageing populations¹⁹. Other longitudinal cohorts have similarly reported adverse cognitive outcomes in relation to tooth loss or impaired dentition, albeit with differences in baseline age structure and cognitive phenotyping^{20,21}. Neuropathology-oriented work has additionally raised the possibility that late-life oral status may track earlier-life inflammatory exposures that intersect with dementia vulnerability²². Against this background, our principal finding was that baseline natural tooth count was not independently associated with incident dementia after accounting for sociodemographic, lifestyle, and functional covariates, whereas functional limitation showed a strong gradient and denture use was associated with lower dementia hazard.

A null association between baseline tooth count and incident dementia in the oldest-old is not necessarily discordant with prior literature, because several features of late-life cohorts can compress or obscure incremental contributions of distal markers. First, tooth count at a single wave may inadequately represent the relevant exposure window if cumulative oral inflammation or long-term masticatory impairment is what matters biologically⁷. Second, time-varying confounding is particularly plausible for oral health, because comorbidity accumulation, healthcare access, nutrition, and frailty can evolve jointly with both oral status and cognitive trajectories⁹. Third, in very old populations, death is a strong competing event that can alter the observed relationship between baseline risk factors and dementia incidence, especially across multi-year survey intervals¹⁴. Finally, dementia risk at advanced ages is shaped by multiple interacting domains, and later-life associations may be dominated by broader vulnerability profiles rather than any single baseline marker¹. From this perspective, our findings add an important boundary condition: baseline tooth count alone may not provide additional prognostic information for incident dementia once functional status and major covariates are considered in a very old cohort.

The prominent association between ADL limitation and incident dementia in our models is consistent with the clinical reality that functional decline and cognitive decline frequently co-evolve in later life²³. Longitudinal evidence indicates that IADL and ADL changes can begin years before a formal dementia diagnosis, supporting the

interpretation of functional limitation as an early marker along the dementia continuum rather than a purely downstream consequence²⁴. This directly addresses the concern about directionality: functional limitation may reflect prodromal neurodegeneration, and thus adjusting for ADL should not be interpreted as demonstrating mediation²³. Instead, our modelling contrast should be read as a cautious, mediation-oriented specification that tests whether estimates materially change after accounting for a strongly dementia-proximal domain, while recognizing that such adjustment can partially condition on early manifestations of disease²⁵. The persistence of the ADL gradient in the landmark analysis, together with the near-null tooth-count estimates across specifications, supports the robustness of the main conclusion while still leaving open the possibility that oral health is linked to dementia through pathways not captured by baseline tooth count alone.

A notable and clinically relevant signal in our study was that denture use was associated with a lower hazard of incident dementia after multivariable adjustment, even though baseline tooth count itself was not associated with dementia incidence. This pattern is not unprecedented: in community-dwelling older adults, denture use has been reported to mitigate cognitive risks associated with tooth loss, implying that oral rehabilitation may modify the functional consequences of missing teeth²⁶. A large prospective cohort from China similarly reported slower cognitive decline among older adults with partial tooth loss who used dentures, which aligns with our direction of association¹². Cross-sectional evidence in Chinese older adults has also linked denture use to better cognitive status among those with tooth loss, although such designs cannot disentangle cause from consequence²⁷. Recent quantitative syntheses have further suggested that denture restoration may be associated with a reduced risk of cognitive impairment, and that rehabilitation could attenuate the adverse cognitive gradient associated with increasing tooth loss²⁸. Related clinical and observational work has likewise supported a positive association between replacing missing teeth with dentures and cognitive outcomes, reinforcing biological plausibility²⁹.

Mechanistically, denture use may capture more than tooth replacement. Restoring masticatory function may improve dietary variety and nutritional adequacy, and may preserve sensory-motor stimulation that engages frontotemporal networks implicated in cognition¹⁰. Systematic synthesis of neurophysiologic studies has suggested that prosthodontic rehabilitation can influence regional brain activity, providing a potential pathway linking oral function to neurocognitive resilience¹¹. At the same time, the intervention evidence base remains mixed, and recent systematic review work emphasizes heterogeneity in populations, interventions, and cognitive outcomes, highlighting the need for more rigorous designs before causal claims are made¹³. Importantly, denture use can also act as a proxy for healthcare engagement, socioeconomic resources, self-care capacity, and social participation, any of which could confound observed associations³⁰. Additionally, cognitive decline itself may reduce uptake, maintenance, or effective use of dentures, which would bias observational estimates toward an apparent protective association if denture non-use partly reflects early cognitive or functional impairment²³.

Several methodological aspects strengthen interpretability of our findings. Because dementia onset was observed only at discrete survey waves, discrete-time hazard modelling is a standard and appropriate approach for interval-censored outcomes in longitudinal surveys³¹. We used participant-level clustering with robust variance estimation to account for repeated person-interval records and within-person correlation, improving inferential stability under common longitudinal-data conditions³². The landmark design is also a widely used strategy to reduce bias from early events that may reflect reverse causation, and its concordance with our main estimates supports robustness³³. Finally, our interpretation of ADL adjustment was intentionally conservative: given the potential for overadjustment when conditioning on variables that may be downstream or on the causal pathway, we treated attenuation patterns as consistency checks rather than formal decomposition.

This study has limitations that should be considered when interpreting the results. Dementia identification in survey-based cohorts is necessarily imperfect, and outcome misclassification that is unrelated to baseline tooth status would be expected to dilute associations toward the null, potentially obscuring modest effects³⁴. More broadly, misclassification can introduce bias whose direction depends on the specific error structure, so null findings should be interpreted with appropriate caution³⁵. Attrition and missing follow-up dementia assessments may also introduce selection bias if loss to follow-up is related to both oral health and dementia risk³⁶. Residual confounding by lifetime oral disease history, cumulative vascular risk, depressive symptoms, and dietary patterns is possible, and time-varying confounding remains difficult to fully address with baseline-only exposures. Finally, competing mortality is substantial in very old cohorts and can complicate etiologic interpretation of incident dementia analyses across long intervals.

Future work could extend these findings by moving beyond a single baseline oral snapshot. Repeated measurement of tooth status and oral function would enable trajectory-based analyses that better capture dynamic exposure patterns and reduce misclassification of long-term oral experience. Integrating time-updated denture status and objective masticatory performance may help differentiate biological tooth retention from functional rehabilitation and clarify which dimension is most relevant to cognitive ageing. Designs that explicitly account for competing mortality and informative dropout would further strengthen inference in oldest-old cohorts. Finally, pragmatic clinical and quasi-experimental studies that evaluate timely prosthodontic rehabilitation alongside standardized cognitive outcomes are needed to determine whether the denture association reflects causal benefit or confounding by health-seeking behavior and preserved self-care capacity. Taken together, these findings suggest that, among the oldest-old, research and clinical efforts may be more fruitfully directed toward preserving overall function and promoting timely prosthodontic rehabilitation rather than focusing solely on baseline tooth retention.

Conclusion

In this national cohort of Chinese adults aged 65 years and older, baseline natural tooth count was not clearly associated with incident dementia across multiple model specifications. Functional limitation was strongly associated with subsequent dementia

onset, and denture use showed an inverse association after multivariable adjustment. These findings suggest that, in very old populations, oral rehabilitation and overall functional status may provide more informative signals for dementia risk stratification than baseline tooth count alone, and they support further longitudinal work that models oral health and rehabilitation as time-varying processes.

Supplementary Materials:

Table S1. Association between baseline natural tooth count and ADL score at baseline

Variable	β (95% CI)	<i>P</i> value
Baseline tooth count (ref: ≥ 20 teeth)		
0 teeth	0.06 (-0.00–0.12)	0.052
1–9 teeth	-0.03 (-0.08–0.02)	0.247
10–19 teeth	-0.05 (-0.11–0.00)	0.059
Age (Per 1-year increase)	0.01 (0.01–0.02)	<0.001
Sex (ref: Female)		
Male	-0.05 (-0.09–0.01)	0.024
Education (ref: ≥ 7 years)		
0 years	-0.06 (-0.12–0.00)	0.059
1–6 years	-0.07 (-0.12–0.01)	0.026
Missing	-0.29 (-1.03–0.46)	0.456
Marital status (ref: Married)		
Not married	0.00 (-0.04–0.04)	0.998
Residence (ref: Urban)		
Rural	-0.12 (-0.15–0.08)	<0.001
Current smoking (Yes vs No)	-0.04 (-0.09–0.00)	0.069
Current drinking (Yes vs No)	-0.04 (-0.08–0.01)	0.098
Regular exercise (Yes vs No)	-0.17 (-0.20–0.13)	<0.001
Sleep duration (ref: <7 h)		
7–9 h	-0.07 (-0.11–0.03)	<0.001
>9 h	0.04 (-0.01–0.09)	0.088
Denture use (Yes vs No)	-0.02 (-0.07–0.02)	0.241
BMI (ref: <18.5 kg/m²)		
18.5–23.9 kg/m ²	0.01 (-0.03–0.05)	0.611
24.0–27.9 kg/m ²	0.03 (-0.03–0.08)	0.375
≥ 28.0 kg/m ²	0.12 (0.02–0.22)	0.024
Missing	1.31 (1.15–1.48)	<0.001

Linear regression model for ADL score, adjusted for baseline covariates.

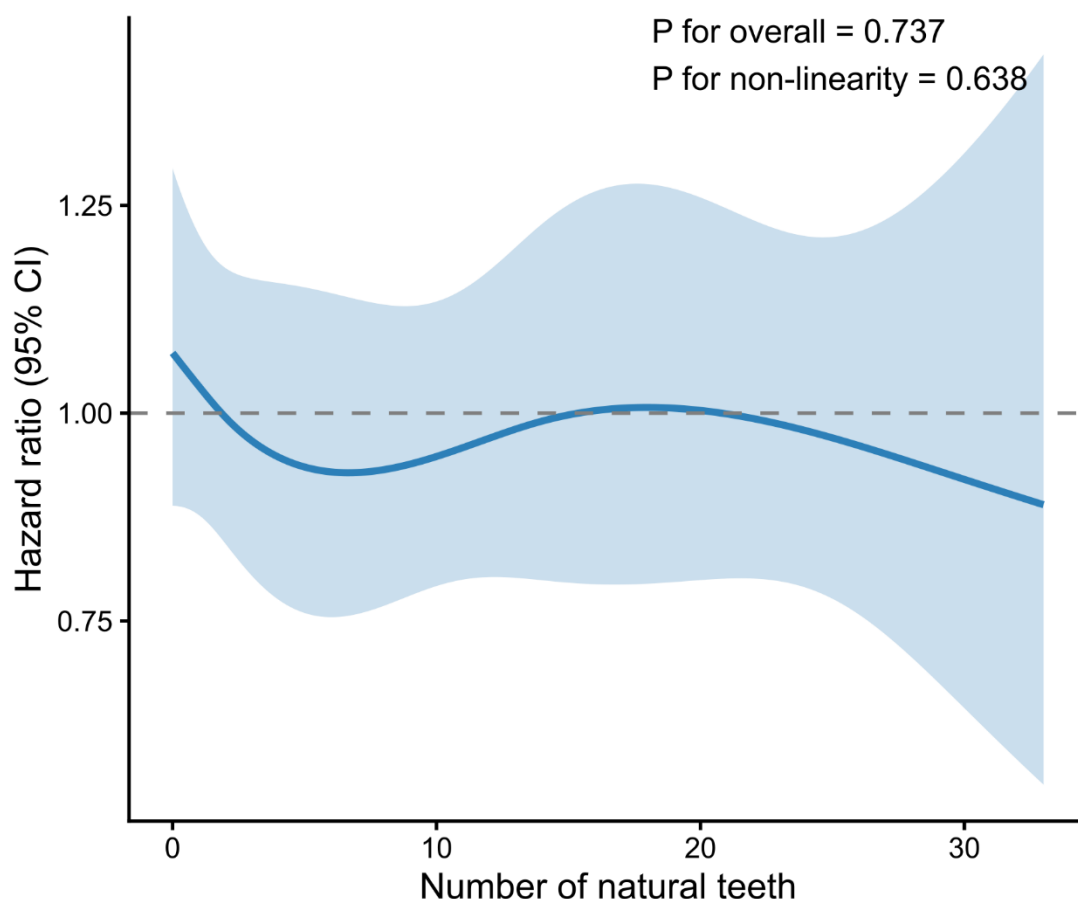


Figure S1. Restricted cubic spline analysis of baseline natural tooth count and incident dementia.

Table S2. TAssociation between baseline natural tooth count and incident dementia in models without ADL covariates

Variable	HR (95% CI)	P value
Baseline tooth count (ref: ≥ 20 teeth)		
0 teeth	1.15 (0.82–1.62)	0.423
1–9 teeth	1.01 (0.74–1.40)	0.933
10–19 teeth	0.87 (0.62–1.23)	0.439
Time period (ref: 2008–2011)		
2011–2014	1.06 (0.86–1.32)	0.570
2014–2018	1.15 (0.83–1.59)	0.393
Age (Per 1-year increase)	1.05 (1.04–1.06)	<0.001
Sex (ref: Female)		
Male	0.80 (0.61–1.04)	0.098
Education (ref: ≥ 7 years)		
0 years	0.76 (0.52–1.10)	0.149
1–6 years	0.78 (0.54–1.12)	0.174
Marital status (ref: Married)		
Not married	1.10 (0.85–1.42)	0.488
Residence (ref: Urban)		

Variable	HR (95% CI)	P value
Rural	0.90 (0.74–1.10)	0.319
Current smoking (Yes vs No)	0.91 (0.67–1.23)	0.530
Current drinking (Yes vs No)	0.88 (0.67–1.17)	0.397
Regular exercise (Yes vs No)	0.77 (0.61–0.96)	0.021
Sleep duration (ref: <7 h)		
7–9 h	0.79 (0.62–0.99)	0.044
>9 h	1.04 (0.81–1.33)	0.785
Denture use (Yes vs No)	0.78 (0.61–0.98)	0.033
BMI (ref: <18.5 kg/m²)		
18.5–23.9 kg/m ²	1.11 (0.89–1.38)	0.369
24.0–27.9 kg/m ²	1.31 (0.94–1.81)	0.110
≥28.0 kg/m ²	1.69 (1.00–2.84)	0.050
Missing	0.89 (0.40–2.01)	0.786

Discrete-time complementary log-log model with cluster-robust standard errors by participant (id), excluding ADL covariates.

Table S3. Sensitivity analysis using continuous ADL score

Variable	HR (95% CI)	P value
Baseline tooth count (ref: ≥20 teeth)		
0 teeth	1.13 (0.80–1.59)	0.503
1–9 teeth	1.02 (0.74–1.40)	0.908
10–19 teeth	0.89 (0.63–1.25)	0.500
Follow-up interval (ref: 2008–2011)		
2011–2014	1.09 (0.88–1.35)	0.428
2014–2018	1.18 (0.86–1.64)	0.305
Age (Per 1-year increase)	1.05 (1.03–1.06)	<0.001
Sex (ref: Female)		
Male	0.81 (0.62–1.06)	0.127
Education (ref: ≥7 years)		
0 years	0.77 (0.53–1.12)	0.173
1–6 years	0.80 (0.56–1.14)	0.217
Marital status (ref: Married)		
Not married	1.11 (0.85–1.44)	0.439
Residence (ref: Urban)		
Rural	0.96 (0.78–1.17)	0.662
Current smoking (Yes vs No)	0.93 (0.69–1.25)	0.622
Current drinking (Yes vs No)	0.90 (0.68–1.20)	0.479
Regular exercise (Yes vs No)	0.82 (0.66–1.03)	0.096
Sleep duration (ref: <7 h)		
7–9 h	0.81 (0.64–1.02)	0.071
>9 h	1.03 (0.80–1.32)	0.810
ADL score (continuous)		
ADL score (per 1-point)	1.26 (1.17–1.36)	<0.001

Variable	HR (95% CI)	P value
Denture use (Yes vs No)	0.79 (0.62–1.00)	0.046
BMI (ref: <18.5 kg/m ²)		
18.5–23.9 kg/m ²	1.09 (0.87–1.36)	0.464
24.0–27.9 kg/m ²	1.28 (0.93–1.78)	0.132
≥28.0 kg/m ²	1.60 (0.94–2.71)	0.081
Missing	0.63 (0.28–1.43)	0.268

Discrete-time complementary log-log model with cluster-robust standard errors by participant. Covariates were the same as in Table 2, except that categorical ADL limitation was replaced by the continuous ADL score. Hazard ratios for ADL score are reported per 1-point increase. ADL score was calculated as the sum of six ADL items, with higher scores indicating greater functional limitation. *P* values were computed using the same cluster-robust variance estimator.

Table S4. Landmark analysis of the association between baseline natural tooth count and incident dementia

Variable	HR (95% CI)	P value
Baseline natural tooth count (Reference: 0 teeth)		
1–9 teeth	0.98 (0.66–1.47)	0.938
10–19 teeth	0.80 (0.47–1.34)	0.383
≥20 teeth	1.09 (0.64–1.83)	0.752
Follow-up interval (Reference: 2011–2014)		
2014–2018	1.12 (0.80–1.58)	0.517
Age, per 1-year increase	1.05 (1.03–1.07)	<0.001
Sex (Reference: Female)		
Male	0.76 (0.49–1.16)	0.170
Education (Reference: ≥7 years)		
0 years	0.81 (0.45–1.46)	0.455
1–6 years	0.95 (0.55–1.63)	0.844
Marital status (Reference: Married)		
Not married	1.13 (0.77–1.65)	0.528
Residence (Reference: Urban)		
Rural	0.83 (0.61–1.14)	0.246
Current smoking (Yes vs No)	1.09 (0.70–1.71)	0.692
Current alcohol drinking (Yes vs No)	0.65 (0.40–1.05)	0.079
Regular exercise (Yes vs No)	0.93 (0.66–1.31)	0.679
Sleep duration (Reference: <7 h)		
7–9 h	0.85 (0.60–1.22)	0.387
>9 h	1.12 (0.74–1.68)	0.592

Variable	HR (95% CI)	P value
ADL limitations (Reference: ≥ 2 limitations)		
0 limitations	0.40 (0.21–0.75)	0.002
1 limitation	0.76 (0.34–1.67)	0.475
Denture use (Yes vs No)	0.94 (0.67–1.34)	0.751
BMI (Reference: <18.5 kg/m²)		
18.5–23.9 kg/m ²	1.00 (0.70–1.44)	0.981
24.0–27.9 kg/m ²	1.18 (0.71–1.94)	0.526
≥ 28.0 kg/m ²	1.32 (0.59–2.99)	0.501
Missing	0.75 (0.19–2.98)	0.689

Hazard ratios (HRs) and 95% confidence intervals (CIs) were estimated using a discrete-time complementary log–log model with participant-level cluster-robust standard errors. Participants who developed dementia during 2008–2011 were excluded, and follow-up began in 2011. The missing-education indicator was retained in the model but is not reported because of sparse data and unstable estimation. ADL, activities of daily living; BMI, body mass index; CI, confidence interval; HR, hazard ratio.

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