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Original Research

The Association between Number of Teeth and Cognitive Frailty in Older Adults: A Cross-Sectional Study

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Abstract

OBJECTIVES: This study aimed to explore the association between number of teeth and cognitive frailty in American older adults.
DESIGN: Cross-sectional study.
SETTING: Community.
PARTICIPANTS: The participants were 1,531 community-dwelling older adults aged 60 or older from the NHANES database.
METHODS: Frailty was assessed using a 49-item frailty index, with a cut-off value for frailty of more than 0.21. Cognitive dysfunction was evaluated by the Digit-Symbol Coding Test (DSCT), with the cut-off being below the lowest interquartile range (scores ≤37). Cognitive frailty was defined as participants who suffered from both frailty and cognitive dysfunction. Oral health indicators included number of teeth and other factors, such as the presence of gum disease, daily use of dental floss, daily use of mouthwash and self-rated oral health. Multivariable logistic regression models were used to explore the relationship between number of teeth and cognitive frailty.
RESULTS: The mean age of the total sample was 69.67 (SD=6.60) years, and 52.71% (n=807) were female. Our study suggests there was a negative association between number of teeth and cognitive frailty (OR =0.98,95%CI:0.96-0.99, P=0.044) after controlling for potential confounding factors. In addition, older adults with 20 or more teeth had lower odds of being cognitively frail (OR=0.66,95%CI:0.44-0.99, P=0.046) than individuals who had less than 20 teeth.
CONCLUSION: This study suggests that older adults who have more teeth are associated with a lower risk of cognitive frailty. This finding highlights the importance of maintaining as many teeth as possible throughout life and into old age. Cohort studies will be required in the future to determine this relationship.

Key words: Teeth, cognitive frailty, oral health, cross-sectional.

Introduction

The number of older adults is rapidly increasing across the world, thanks to developments in science and comprehensive healthcare. With aging, older adults usually experience multiple comorbidities and endure declining function, leading to a high proportion of adults suffering from frailty and cognitive dysfunction. Frailty and cognitive dysfunction are two common geriatric syndromes that can lead to many adverse outcomes, such as falls, disability, hospitalization and rehospitalization, and even death (1, 2). In 2013, the International Academy on Nutrition and Aging (IANA) and the International Association of Gerontology and Geriatrics (IAGG) (IANA/IAGG) created a new concept of cognitive frailty, defined as older adults with physical frailty and cognitive dysfunction without a clear clinical diagnosis of dementia (3). Since the first introduction of cognitive frailty, multiple studies have explored the association between cognitive frailty and adverse outcomes, suggesting that individuals with cognitive frailty are at more risk than individuals with only frailty or only mild cognitive impairment (4, 5). Therefore, identifying the risk of cognitive frailty at an early stage and conducting interventions will improve health-related outcomes.

Several factors are associated with cognitive frailty, including age, being female, malnutrition, and sedentary behavior (6). However, currently, no study has investigated the association between oral health and cognitive frailty. Oral health is receiving more attention from the geriatric field, because older adults commonly suffer poor oral health, such as tooth loss, poor chewing ability and dysphagia (7, 8). According to the new definition of oral health, people who do not have any oral disease can smile, speak, and laugh without any disorder or social or psychological problems (9). In fact, many studies have investigated oral health and cognition, indicating that people with poor oral health have a high risk of cognitive impairment and dementia (10-12). Recently, a meta-analysis reported a dose-response relationship between a person's number of teeth and cognitive impairment or dementia (13). In addition, the relationship between teeth and frailty was also confirmed by a cross-sectional study and cohort study (14). In 2021, Kuo et al (15) conducted a survey of older adults living in rural communities, and found a negative association between a person's number of teeth and their physical frailty, with the OR being 0.98(95%CI:0.96-0.99, P=0.006). In addition, Castrejón-Pérez conducted a cohort study with a three-year follow-up, and found that in older adults, each additional tooth could decrease the rate of physical frailty by 5% (16). Considering this previous evidence of the relationship between tooth health and frailty or cognitive impairment, there is increased interest in understanding the association between

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tooth loss and cognitive frailty. Therefore, our study aimed to investigate the association between number of teeth and cognitive frailty using the NHANES database. We speculate that older adults who suffer tooth loss can end up at high risk of cognitive frailty.

Methods

Data source

These data originated from NHANES, a large survey of Americans investigating nutritional status and other related health variables. All data were conducted by multistage sampling design. We downloaded all data from the U.S. Centers for Disease Control and Prevention. In our study, we combined the data from the 2011-2014 NHANES of individuals aged 60 years old or older, resulting in 3,632 older adults. After removing the missing data from any variables, there were 1,531 individuals for our final analysis.

Demographic variables

Demographics, including age, gender, race, education, and marital status, were recorded by trained investigators using a computer-assisted personal interviewing system. Education was classified as four-level degrees (less than 12 grades, high school graduate, some college and college graduate and above) and race was defined as Non-Hispanic White, Non-Hispanic Black and others. Marital status was presented as married, widowed or divorced and others.

Frailty definition

The frailty index was originally proposed and validated based on an accumulation of deficits by Mitnitski et al (17). In our study, we defined frailty using the frailty index that calculated a total score of 49 deficits and divided it by 49. The frailty index was based on a standard procedure from a previous study (18), and the detailed calculation points for each item are shown in supplemental Table 1. The frailty index, encompassing multiple systems, included 13 chronic diseases, seven depressive symptoms, one item cognitive complaint, BMI, handgrip strength, polypharmacy, 15 items for activities of daily living, one item of general health status, three items of healthcare utilization, and six items of laboratory values. Based on previously published frailty index criteria, a score of more than 0.21 confirmed a person's frailty (19).

Cognitive dysfunction

The Wechsler Adult Intelligence Scale III Digit-Symbol Coding Test (DSCT), which assesses cognitive function in older adults, was used to evaluate visual processing speed, working memory and attention. The total DSCT score ranged from 0 to 133, and the higher the score, the better the cognitive function. According to a previous study, the cut-off value for cognitive dysfunction was below the lowest of the interquartile range (<=37) in this population group (20).

Number of teeth

The section on oral health-dentition provides the examination results of tooth count. We calculated each tooth count (from #1 to #32) if the variable item was tooth not present, meaning tooth loss. Furthermore, we also classified the number of teeth into two groups (>=20 versus <20).

Inadequate nutritional intake

We extracted the micronutrient intake data from the first day dietary recalls. We calculated participant nutritional intake amount according to the dietary recommendations for older adults suggested by the National Institutes of Health. This criterion was used in a previous study (21). The cut-off for defining 13 micronutrients is shown in supplemental Table 2. In our study, the higher the number indicating inadequate nutritional intake, the more severe the malnutrition.

Covariate definition

Other oral health information, such as self-rating of oral health, gum disease, treatment of gum disease, daily use of dental floss/device and daily use of mouthwash, was also extracted. In addition, behavioral factors, such as sleep disorders and physical activity, were extracted in our study. According to a previous study, physical activity, assessed by the Global Physical Activity Questionnaire, was grouped into three categories: inactivity, insufficient activity, and sufficient activity (22).

Statistical Analysis

Descriptive analysis was used to describe continuous and categorical variables with mean (standard deviation) and frequency. T-test and Chi-square test were adopted to detect the differences between two groups (>=20 and <20) in terms of various variables. In addition, we used the Kruskal-Wallis test when the variable was skewed distribution. We used multivariable logistic regression models to explore the association between number of teeth or teeth group and cognitive frailty, with the results presented by odds ratio and a 95% confidence interval. We selected the potential confounding factors through univariate analysis of significant differences (P<0.05). We displayed four models: the unadjusted model; model I was adjusted for age, education, and gender; model II was adjusted for age, education, gender, self-rated oral health, treatment for gum disease, physical activity, and daily use of dental floss; model III adjusted potential variables based on model II plus inadequate nutritional intake. There was no risk of collinearity in these adjusted models based on variance inflation factor. In addition, a generalized additive model was conducted to explore whether there was a non-relationship between number of teeth and cognitive frailty. Finally, we did

Table 1. Baseline characteristics of total sample according to number of teeth

Characteristics	Total	Number of teeth categories		P-value
		<20	>=20	
N	1531	609	922	
Age (mean, SD)	69.67 ± 6.60	70.68 ± 6.48	69.01 ± 6.60	<0.001
Number of teeth (median, IQR)	23.00 (9.50-27.00)	6.00 (0.00-13.00)	26.00 (24.00-28.00)	<0.001
Inadequate nutritional intake (mean, SD)	8.82 ± 2.77	9.31 ± 2.66	8.50 ± 2.79	<0.001
Days using dental floss/device (mean, SD)	3.50 ± 3.10	1.88 ± 2.81	4.57 ± 2.81	<0.001
Days using mouthwash (mean, SD)	3.30 ± 3.21	3.50 ± 3.24	3.16 ± 3.19	0.044
Gender (n, %)				0.999
Male	724 (47.29%)	288 (47.29%)	436 (47.29%)	
Female	807 (52.71%)	321 (52.71%)	486 (52.71%)	
Marital status (n, %)				<0.001
Married	931 (60.85%)	312 (51.23%)	619 (67.21%)	
Widowed or divorced	465 (30.39%)	228 (37.44%)	237 (25.73%)	
Other	134 (8.76%)	69 (11.33%)	65 (7.06%)	
Sleep disorder (n, %)				0.927
Yes	452 (29.52%)	179 (29.39%)	273 (29.61%)	
No	807 (52.71%)	430 (70.61%)	649 (70.39%)	
Race (n, %)				<0.001
Other	379 (24.76%)	159 (26.11%)	220 (23.86%)	
Non-Hispanic White	832 (54.34%)	261 (42.86%)	571 (61.93%)	
Non-Hispanic Black	320 (20.90%)	189 (31.03%)	131 (14.21%)	
Education (n, %)				<0.001
Less than twelvth grade	327 (21.37%)	216 (35.47%)	111 (12.05%)	
High school graduate	361 (23.59%)	176 (28.90%)	185 (20.09%)	
Some college	435 (28.43%)	144 (23.65%)	291 (31.60%)	
College graduate above	407 (26.60%)	73 (11.99%)	334 (36.26%)	
Self-rated oral health (n, %)				<0.001
Excellent/very good	620 (40.58%)	178 (29.37%)	442 (47.94%)	
Good	570 (37.30%)	239 (39.44%)	331 (35.90%)	
Fair	249 (16.30%)	123 (20.30%)	126 (13.67%)	
Poor	89 (5.82%)	66 (10.89%)	23 (2.49%)	
Gum disease (n, %)				0.953
Yes	233 (15.35%)	92 (15.28%)	141 (15.39%)	
No	1285 (84.65%)	510 (84.72%)	775 (84.61%)	
Treatment for gum disease (n, %)				<0.001
Yes	430 (28.14%)	135 (22.24%)	295 (32.03%)	
No	1098 (71.86%)	472 (77.76%)	626 (67.97%)	
Frailty (n, %)				<0.001
No	951 (62.12%)	326 (53.53%)	625 (67.79%)	
Yes	580 (37.88%)	283 (46.47%)	297 (32.21%)	
Cognitive dysfunction (n, %)				
No	1147 (74.92%)	362 (59.44%)	785 (85.14%)	
Yes	384 (25.08%)	247 (40.56%)	137 (14.86%)	
Physical activity (n, %)				0.143
Inactivity	1034 (67.54%)	425 (69.79%)	609 (66.05%)	
Insufficient activity	138 (9.01%)	45 (7.39%)	93 (10.09%)	
Sufficient activity	359 (23.45%)	139 (22.82%)	220 (23.86%)	
Cognitive frailty (n, %)				<0.001
No	1346 (87.92%)	489 (80.30%)	857 (92.95%)	
Yes	185 (12.08%)	120 (19.70%)	65 (7.05%)	

a subgroup analysis of the association between teeth groups and cognitive frailty in terms of gender, older age, education, race, sleep disorder, gum disease and treatment for gum disease. We considered a P-value of less than 0.05 as a significant difference. Software packages R and EmpowerStats software were used to complete all data analyses.

Sensitivity Analyses

Sensitivity analyses were performed to confirm the main findings of the results. First, as for any cross-sectional study, the risk of reversal causality is very high. To reduce this important potential bias, we undertook a sensitivity analysis by removing individuals with the worst scores in both cognition and FI; according to a previous study (23), removing 10% of people with the worst cognition and 10% with the worst FI would be acceptable. Second, we built a modified version of frailty phenotype based on previous studies (24, 25). The detailed items for the definition of modified frailty phenotype are shown in supplemental file1. In addition, we reproduce our main findings in a sensitivity analysis with the definition of cognitive frailty by combining a modified frailty phenotype with cognitive impairment.

Results

Participant characteristics

There were 1,531 older adults in this study. The mean age of the total sample was 69.67 (SD=6.60) years and 52.71% (n=807) were female. More than half of the subjects were married (60.85%) and unlikely to participate in physical activity (67.54%). Of the total sample size, the prevalence of cognitive frailty was 12.08% (n=185), and the median number of teeth was 23.00 (IQR: 9.50-27.00). The majority of participants reported their oral health as good or better (77.7%). The education distribution in this entire sample is very close. Participants with fewer than 20 teeth had less education and a higher percentage of poor self-rated oral health. In addition, older adults with fewer than 20 teeth suffered a higher proportion of frailty (46.47%), cognitive dysfunction (40.56%), and cognitive frailty (19.70%). There were significant differences between two groups of teeth categories (>20 versus >=20) in terms of age, marital status, inadequate nutritional intake, race, education and treatment of gum disease (both P-value<0.05), whereas gender, sleep disorder, gum disease, physical activity did not show a significant difference. All of the detailed information about the total sample and two teeth category groups are shown in Table 1.

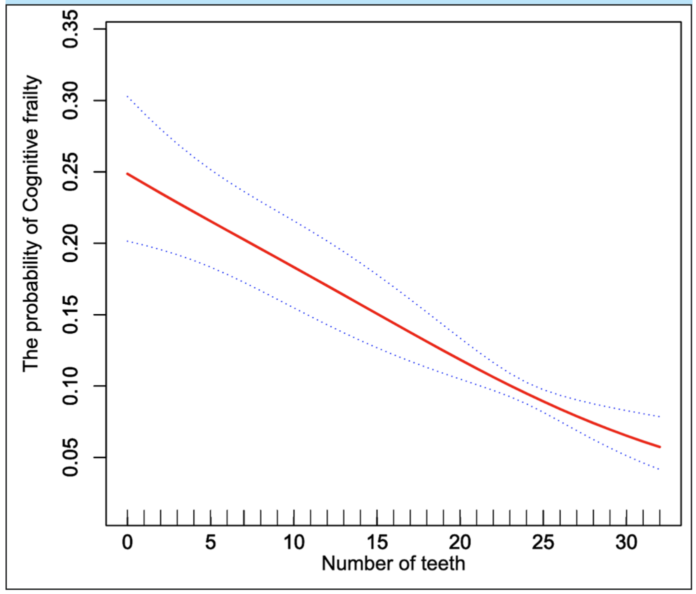
Univariate analysis for cognitive frailty

Table 2 summarizes the results of the univariate analysis of cognitive frailty. Overall, mean age and inadequate nutritional intake among older adults with cognitive frailty were higher than in those without cognitive frailty, with significant differences. In addition, the median number of teeth was higher in the non-cognitively frail group than in the cognitively frail group. In terms of other oral health variables, older adults with cognitive frailty were more likely to have poor self-rated oral health and were unlikely to be receiving treatment for gum disease. The mean daily of use dental floss/device in older adults with cognitive frailty was lower than in those without cognitive frailty. Furthermore, those with cognitive frailty were more likely to have less education (51.35%) and higher rates of a sleep disorder (43.78%), experiencing more possibility of inactivity (78.92%). However, there was no significant difference between these two groups (cognitive frailty versus non-cognitive frailty) in terms of gum disease, gender, and daily use of mouthwash.

The association between number of teeth and cognitive frailty

The results of the generalized additive model indicate a linear relationship between number of teeth and cognitive frailty, suggesting that with an increase in number of teeth, the lower the probability of cognitive frailty (Figure 1).

Figure 1. A linear relationship between number of teeth and probability of cognitive frailty by a generalized additive model



Multivariable adjusted regression models

Table 3 shows the results of multivariable logistic regression models for the association between number of teeth and cognitive frailty. In the unadjusted model, there was a negative association between number of teeth and cognitive frailty, suggesting that each addition of one tooth could result in a 6% decrease in the probability of cognitive frailty. After fully adjusted variables such as age, gender, education, self-rated oral health, physical activity, treatment for gum disease and daily use of dental floss and inadequate nutritional, intake, there was still a negative association between number of teeth and cognitive frailty (OR =0.98,95%CI:0.96-0.99, P=0.044).

Table 2. Univariate analysis for cognitive frailty

	Cognitive frailty		OR (95%CI)	P-Value
	0	1		
Gender (n, %)				
Male	633 (47.03%)	91 (49.19%)	Reference	
Female	713 (52.97%)	94 (50.81%)	0.92 (0.67, 1.25)	0.5810
Age (mean, SD)	69.33 ± 6.54	72.16 ± 6.48	1.07 (1.04, 1.09)	<0.0001
Inadequate nutritional intake (mean, SD)	8.73 ± 2.78	9.45 ± 2.59	1.10 (1.04, 1.17)	0.001
Number of teeth (median, IQR)	23.00 (12.00-27.00)	11.00 (0.00-32.00)	0.95 (0.93, 0.96)	<0.0001
Teeth categories (n, %)				
<20	489 (36.33%)	120 (64.86%)	Reference	
>=20	857 (63.67%)	65 (35.14%)	0.31 (0.22, 0.43)	<0.0001
Sleep disorder (n, %)				
Yes	371 (27.56%)	81 (43.78%)	Reference	
No	975 (72.44%)	104 (56.22%)	0.49 (0.36, 0.67)	<0.0001
Race (n, %)				
Other	321 (23.85%)	58 (31.35%)	Reference	
Non-Hispanic White	762 (56.61%)	70 (37.84%)	0.51 (0.35, 0.74)	0.0004
Non-Hispanic Black	263 (19.54%)	57 (30.81%)	1.20 (0.80, 1.79)	0.3731
Marital status (n, %)				
Married	833 (61.93%)	98 (52.97%)	Reference	
Widowed or divorced	396 (29.44%)	69 (37.30%)	1.48 (1.06, 2.06)	0.0198
Others	116 (8.62%)	18 (9.73%)	1.32 (0.77, 2.26)	0.3139
Education (n, %)				
Less than 12 grades	232 (17.25%)	95 (51.35%)	Reference	
High school graduate	320 (23.79%)	41 (22.16%)	0.31 (0.21, 0.47)	<0.0001
Some college	401 (29.81%)	34 (18.38%)	0.21 (0.14, 0.32)	<0.0001
College graduate	392 (29.14%)	15 (8.11%)	0.09 (0.05, 0.16)	<0.0001
Self-rated oral health (n, %)				
Excellent/very good	571 (42.52%)	49 (26.49%)	Reference	
Good	500 (37.23%)	70 (37.84%)	1.63 (1.11, 2.40)	0.0126
Fair	202 (15.04%)	47 (25.41%)	2.71 (1.76, 4.17)	<0.0001
Poor	70 (5.21%)	19 (10.27%)	3.16 (1.76, 5.68)	0.0001
Days using dental floss/device (mean, SD)	3.67 ± 3.09	2.30 ± 2.95	0.86 (0.82, 0.91)	<0.0001
Days using mouthwash (mean, SD)	3.24 ± 3.22	3.71 ± 3.14	1.05 (1.00, 1.10)	0.0615
Gum disease (n, %)				
Yes	205 (15.36%)	28 (15.30%)	Reference	
No	1130 (84.64%)	155 (84.70%)	1.00 (0.65, 1.54)	0.9845
Treatment for gum disease (n, %)				
Yes	390 (29.04%)	40 (21.62%)	Reference	
No	953 (70.96%)	145 (78.38%)	1.48 (1.03, 2.15)	0.0363
Physical activity (n, %)				
Inactivity	888 (65.97%)	146 (78.92%)	Reference	
Insufficient activity	123 (9.14%)	15 (8.11%)	0.74 (0.42, 1.30)	0.2991
Sufficient activity	335 (24.89%)	24 (12.97%)	0.44 (0.28, 0.68)	0.0003

Furthermore, when we categorized the number of teeth as more than and equal to 20 and less than 20, the results found that individual with 20 and more than teeth had lower odds of having cognitive frailty (OR=0.31,95CI%:0.22-0.42), compared to those with less than 20 teeth in the unadjusted model. The odds ratio for the association between teeth category and cognitive frailty gradually attenuated after controlling for age, gender and education in model I. In addition, after controlling for age, gender, education, self-rated oral health, physical activity, treatment for gum disease and daily use of dental floss, older adults with 20 and more teeth still had lower odds of being cognitively frail, (OR=0.62,95%CI:0.42-0.91, P=0.015)

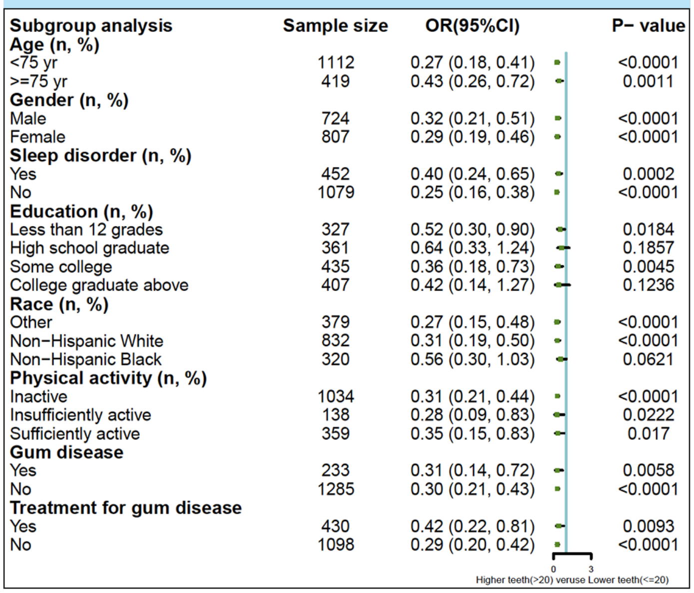
Table 3. Multivariable regression models for the association between number of teeth and cognitive frailty

Exposure	Non-adjusted	Model I	Model II	Model III
Teeth categories	**OR (95%CI) P-value**	**OR (95%CI) P-value**	**OR (95%CI) P-value**	
<20	1.0	1.0	1.0	1.0
>=20	0.31 (0.22, 0.42) <0.00001	0.54 (0.38, 0.77) 0.0007	0.62 (0.42, 0.91) 0.015	0.66(0.44,0.99), 0.046
Number of teeth	0.94 (0.93, 0.96) <0.00001	0.97 (0.96, 0.99) 0.001	0.97 (0.96, 0.99) 0.025	0.98(0.96,0.99), 0.044

Results: OR (95%CI) P-value / Outcome: Cognitive frailty; Exposure: Teeth categories; Number of teeth; Non-adjusted model adjusted for: None; Model I adjusted for: Age; Gender; Education; Model II adjusted for: Age; Gender; Education; Self-rated oral health; Physical activity; treatment for gum disease; days using dental floss; Model III adjusted for: Age; Gender; Education; Self-rated oral health; Physical activity; treatment for gum disease; days using dental floss, inadequate nutritional intake

than individuals with less than 20 (model II). In model III, the results showed that after adjusting for potential confounding factors in model II, with the addition of inadequate nutritional intake, the effect size between number of teeth and cognitive frailty was attenuated, with the OR changed from 0.62 (0.42-0.91) to 0.66 (0.44-0.99). Furthermore, the results of two sensitivity analyses (see supplemental Table 3-4) in all the logistical regression models found that there was a significant association between the number of teeth and cognitive frailty.

Figure 2. The subgroup analysis between the association between the number of teeth and cognitive frailty



Subgroup analysis for the association between teeth category and cognitive frailty based on various variables

Subgroup analysis was performed to determine whether this association between number of teeth category (>=20 and <20) and cognitive frailty was different, based on gender, age group (>=75 years and <75 years), education, race, sleep disorder, physical activity, gum disease and treatment for gum disease. The results show the association between a higher number of teeth and the probability of cognitive frailty in both males and females (OR=0.32,95%CI:0.21-0.51 and OR=0.29,95%CI:0.19-0.46). Similar associations were also found across other patient characteristics and clinical variables (Figure 2).

Discussion

We observed, using NHANES data, that tooth loss in older adults is associated with an increased probability of cognitive frailty. In addition, older adults who had 20 or more teeth experienced a lower odds ratio for cognitive frailty. These associations still existed even after controlling for complete potential confounding factors. It is, to the authors' best knowledge, the first study to examine the association between number of teeth and cognitive frailty. This study supports our hypothesis that number of teeth is negatively associated with a higher probability of cognitive frailty.

The prevalence of cognitive frailty in our study was 12.08%, which was higher than the prevalence found in prior studies, which reported the prevalence of cognitive frailty ranging from 2.1% to 5.44% (4, 26). Recently, a systematic review reported that the pooled prevalence of cognitive frailty was 9% (95%CI:8%-11%) among community-dwelling older adults (27). In general, the prevalence of cognitive frailty was influenced by various factors, such as the definition of cognitive frailty, population type, and region (28). In our study, the population was nation-wide, representing older adults in the U.S. The definition of cognitive frailty was defined as older adults with frailty index and cognitive impairment scores below the lowest quartile (scores ≤37) in this study population, using the digit symbol substitution test (DSST). In fact, using the frailty index could lead to higher frailty scores compared to using physical frailty measures, which might be why our study's cognitive frailty prevalence findings were higher than in others.

The relationship between oral health and frailty or cognitive impairment has been widely explored in recent decades. Among the indicators of oral health, tooth loss is the most important. Tooth loss is prevalent among older adults and subsequently affects chewing and occlusion, leading to lower nutritional intake (29). Both cross-sectional studies and cohort studies have found that tooth loss is associated with frailty. In a study of Chinese adults aged 60 or older, individuals with fewer than 20 teeth was associated with high odds of frailty, and this association did not change in either those wearing dentures or those who do not wear dentures (30). In addition, several studies have indicated a negative association between number of teeth and frailty among older adults (21, 31). Furthermore, in 2021, Qi et al. (13) reported a dose-response relationship between number of teeth and cognitive impairment. However, no study has yet explored the association between number of teeth and cognitive frailty. As cognitive frailty is described as an individual being frail, together with mild cognitive impairment but without definite dementia, it is reasonable to assume that tooth loss could increase the risk of cognitive frailty. Our study found a negative relationship between teeth and cognitive frailty, which is very important. Cognitive frailty is a new concept widely applied for early identification of a higher risk of adverse outcomes, given that many studies have reported that cognitive frailty leads to worse mortality or falls than either frailty alone or cognitive impairment alone (32, 33). In addition, the study suggests that cognitive frailty can be reversed (34); therefore, identifying risk factors related to cognitive frailty is very important. Our study indicates that tooth loss is associated with a high risk of cognitive frailty. Many measures can be taken to reduce the possibility of tooth loss, such as early screening for oral health, treating periodontal disease and sustaining good oral hygiene.

The possible mechanism for tooth loss increasing the likelihood of cognitive frailty is complex. First, one possible pathway for tooth loss and cognitive frailty is nutritional status. The oral cavity consists of complex microflora, such as bacteria, fungi and viruses (35). Normally, these microflora exist within a dynamic balance, but poor oral hygiene and other risk factors could lead to major disturbances in the interactions between oral microbes, resulting in oral diseases, such as periodontitis and dental caries (36). When patients suffer from periodontitis and dental caries without medical treatment, they could experience tooth loss; therefore, older adults with tooth loss can reflect major disturbances in oral microbes. Older adults who lost their teeth suffered a decline in chewing ability, leading to major changes in their food selection (37). Older people with tooth loss were likelier to eat soft food than fruits, meat, and vegetables, which could influence the quality of their nutritional intake and eventually augment their risk of malnutrition and lead to cognitive frailty. In our multivariable adjusted regression models, we present four adjustment models. In model III, the results show that after adjusting the potential confounding factors with the addition of inadequate nutritional intake, the effect size between number of teeth and cognitive frailty was attenuated, with the OR changing from 0.62 (0.42-0.91) to 0.66 (0.44-0.99). Therefore, a nutritional pathway for number of teeth and cognitive frailty was existed, based on a 4% odds ratio of the effect size was decreased after controlling for the pathway of inadequate nutritional intake.

Second, some studies proposed the hypothesis of the interplay of oral bacteria, periodontal disease, and cognitive dysfunction, which was seen as playing an important role in the microbiota-gut-brain axis (38). Periodontal disease caused by oral microbiota was the main reason for tooth loss, which could decrease masticatory ability. It has been reported that masticatory disorder is associated with memory deficits (39), and an animal study has also indicated that declining masticatory ability is linked with a reduction in pyramidal cells, resulting in cognitive dysfunction (40). In addition, some studies have shown that oral microbiota might penetrate the brain through systemic circulation or neural access, impacting the risk of cognitive dysfunction (41). Therefore, oral bacteria and tooth loss play an important role in the development of cognitive frailty.

Third, another pathway could be a psychosocial phenomenon. Older adults who suffer tooth loss could have their self-esteem adversely impacted (42). In addition, periodontal bacteria, such as prevotella intermedius, resulting from an unclean oral cavity, could produce volatile sulfur compounds related to halitosis (43). Tooth loss and halitosis could undermine self-confidence, leading to social fears of participating in social activity (44). Once older adults spend a long time staying at home instead of participating in social activities, they could be at high risk of depression. Isabelle Kunrath (45) conducted a study to explore the association between oral health and depression, and found a significant correlation between depressive symptoms and tooth loss, suggesting that older adults with tooth loss had more severe depression. In 2021, Koyama (46) conducted a cross-national study to explore the association between oral health and social isolation. The study results found that older adults without any teeth had a higher risk of social isolation, compared to participants with 20 or more teeth, (OR=1.21,95%CI:1.15-1.27) and those with one to nine teeth were also at higher risk of social isolation (OR=1.19,95%CI:1.15-1.24). These results suggest that tooth loss is associated with social isolation. Furthermore, a recent study of Chinese older adults aged 65 years or older reported that after adjusting potential covariates, there was a significant association between social isolation and fewer remaining teeth or tooth loss, implying that tooth loss might be associated with social isolation (47). As depression and social isolation are both strongly correlated with a high risk of cognitive frailty (48, 49), tooth loss could increase the risk of cognitive frailty through psychosocial effects, such as self-esteem, depression, and social isolation.

The last possible link between teeth and cognitive frailty might be the inflammatory pathway. The most common reason for tooth loss is periodontal disease, which can produce many inflammatory factors, such as interleukin-6 (IL-6), IL-1, C-reactive protein (CRP), and TNF-alpha, reported by previous studies to be associated with frailty (50, 51). In addition, some studies have also indicated that these inflammatory cytokines, increased by periodontal disease, can circulate to the brain through related anatomical pathways. Once these mediators live in the brain, they could possibly stimulate microglia in the brain and contribute to a vicious inflammatory cycle, finally damaging vital neurons and leading to a decline in cognitive function (52).

Our study contains many strengths and drawbacks. First, after searching the PubMed database, our report first explored the association between tooth loss and cognitive frailty, and our results can bring more attention to the association between oral health and cognitive frailty. Second, we used comprehensive statistical analysis to determine this association, such as full adjustment-regression and subgroup analysis, making our results more reliable and credible. Third, we performed a sensitivity analysis by using the definition of cognitive frailty with the combination of cognitive impairment and modified frailty phenotype and the main results found that the number of teeth was associated with high likelihood of cognitive frailty, which was similar to the results when using the frailty index to evaluate whether an individual was frail or non-frail. However, there were some limitations, so we need to be cautious when making recommendations to guide clinical practice. First, this was a cross-sectional study, so it cannot draw conclusions on a cause-and-effect relationship. There might be a bidirectional association between tooth loss and cognitive frailty. When older adults suffer from cognitive frailty, they are less likely to take care of their oral hygiene and attend regular dental appointments, worsening their oral health, including tooth loss. Second, as for any cross-sectional study, the risk of reversal causality is very high. However, we performed a sensitivity analysis by removing the older adults with the worst scores in both cognition and FI, and the main results were unchanged, which confirms our findings in robustness. Third, our study did not collect other confounding factors, such as social isolation, and living environment factors, which might have influenced our results. Third, the NHANES data did not provide any variables on dementia history, and the older adult study participants were not tested using a clinical dementia rating, therefore, our study could not exclude older adults with dementia. This means there could have been some potential error in the association between the number of teeth, and cognitive frailty. A future study needs to be conducted on this issue, to provide a more accurate association.

Conclusion

The findings of our study indicate that number of teeth was negatively associated with cognitive frailty. It is essential to implement an improvement program for oral health, such as routine oral health screening, and education on tooth restoration in older adults. Future prospective cohort studies are warranted to understand the causal association between number of teeth and cognitive frailty.

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