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Original Research

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Relationships among tooth loss, prefrailty, and dietary patterns in community-dwelling older Japanese females: a cross-sectional study

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Conflict of Interest
The authors declare no potential conflicts of interests.

ABSTRACT

BACKGROUND/OBJECTIVES: Poor oral health has been predicted the development of frailty and sarcopenia as well as the subsequent need for long-term care. This cross-sectional study examined the relationships among tooth loss, prefrailty, and dietary patterns in community-dwelling older Japanese females.
SUBJECTS/METHODS: Information on the number of teeth, food consumption, and lifestyle factors was collected from 271 participants aged ≥ 65 yrs using a questionnaire. The number of teeth was self-reported and classified into 2 groups: natural teeth ≥ 20 and natural teeth < 20. Prefrailty was assessed using the Japanese version of the Cardiovascular Health Study. Three dietary patterns ("vegetables and dairy products" [VD], "rice and fish and shellfish" [RF], and "bread and beverages") were adopted from a cluster analysis of the intakes of 20 foods evaluated using the Food Frequency Questionnaire. The odds ratios (ORs) for prefrailty and dietary patterns were calculated using a binary logistic regression analysis.
RESULTS: A total of 267 participants were analyzed, excluding those with frailty (n = 4). The rates of natural teeth < 20 and prefrailty were 57.3 and 37.4%, respectively. Natural teeth < 20 was positively correlated with prefrailty (OR, 4.66; 95% confidence interval [CI], 2.54–8.52) and inversely correlated with VD pattern (OR, 0.43; 95% CI, 0.27–0.69). Furthermore, both VD (OR, 0.38; 95% CI, 0.16–0.91) and RF (OR, 0.26; 95% CI, 0.11–0.62) patterns were inversely correlated with prefrailty.
CONCLUSIONS: Maintaining the number of natural teeth ≥ 20 into old age plays an important role in preventing a prefrailty. The promotion of VD and RF dietary patterns has potential as an effective nutritional strategy for preventing tooth loss and prefrailty.

Keywords: Tooth loss; frailty syndrome; dietary patterns; oral health; female

INTRODUCTION

Population aging is rapidly progressing worldwide. Japan, with the highest aging rate globally, urgently needs to extend healthy life expectancy [1]. Poor oral health is common in the older population [2], and events such as tooth loss can lead to hypoactivity of the

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masticatory system, and, in turn, unhealthy diet patterns, which can negatively influence general health [3]. A Japanese longitudinal study reported that oral health issues (e.g. tooth loss, periodontal disease) are significantly associated with the risk of frailty in the older population [4]. This indicates that oral health predicts the need for subsequent long-term care. Thus, the concept of oral frailty, which occurs as overall physical function declines due to deterioration of oral health, was established [4]. With growing awareness that the recovery and maintenance of oral function may lead to an extended healthy life expectancy [5], the government advocates lifelong dental examinations ("universal oral health checks") as a measure against oral frailty [6]. Frailty affects multiple domains of the body, including gait, mobility, muscle strength, cognition, nutritional status, endurance, and physical activity [7]. Older adults with prefrailty, who are healthier than individuals with frailty, are characterized by a transition between the frailty and non-frailty status [8]. Early interventions for prefrailty may improve quality of life and reduce adverse outcomes [9].

Previous studies reviewed risk factors associated with malnutrition in older adults [10], and showed that the gradual deterioration of the health status and physical function caused by aging [11], including worsening oral health, are important factors contributing to malnutrition in those aged ≥ 65 yrs, suggesting that the restriction of certain foods or food groups from the diet worsens malnutrition in older adults [12]. Nutrition has been identified as one of the essential and easily modifiable risk factors for the prevention of disease [13]. Dietary patterns have recently been the focus of research on the relationship between diet and health at the population level [14,15]. The effects of dietary patterns on health are being increasingly recognized [16], and dietary pattern evaluations were recently confirmed to be an alternative approach to investigate nutrient exposure in nutritional epidemiology [17]. Bollwein *et al.* [18] examined the relationship between healthy dietary patterns with high Mediterranean diet (MED) scores and frailty, and demonstrated that MED scores were significantly lower among older adults with frailty than those with prefrailty and non-frailty. Nakamura *et al.* [19] and Shimazu *et al.* [20] reported that Japanese dietary patterns provide specific health benefits. However, the effects of improving oral health conditions on frailty older adults remain unclear [21]. Observational studies on tooth loss and dietary patterns are limited to that by Ishimiya *et al.* [22]. They demonstrated that tooth loss reduced the intake of vegetables and revealed that lower scores for this dietary pattern were associated with a higher prevalence of cognitive impairment [22]. To the best of our knowledge, the relationships among tooth loss, prefrailty, and dietary patterns have not yet been elucidated, and, thus, warrant further study.

The retention of 20 or more natural teeth has been identified as an acceptable and reasonable standard for appropriate dentition [23]. The Health Japan 21 Project (second term) led by the Ministry of Health, Labour, and Welfare set the goal of the "80-20 Campaign (20 teeth at the age of 80 years)" to prevent tooth loss and maintain/improve oral functions [24].

Therefore, in the present cross-sectional study, we hypothesized that a self-reported number of natural teeth < 20 is associated with prefrailty among community-dwelling older females, and aimed to elucidate the relationships among the number of natural teeth, prefrailty and dietary patterns.

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SUBJECTS AND METHODS

Study design, participants, and setting

This cross-sectional study has been described in detail elsewhere [25]. In brief, participants were 271 healthy older community-dwelling females (age range, 65–84 yrs) attending the Elders College in Kitakyushu city, Japan in 2016. The study items included: the frequency of intake of 39 foods and 10 types of dishes, frailty assessment, age, body weight, height, blood pressure, smoking, alcohol drinking, and number of natural teeth. Using the same participant measurements as in the previous study [25], we clarified previously unreported relationships among tooth loss, prefrailty, and dietary patterns. Based on the findings that older females have a higher prevalence of prefrailty than older males [26], we focused on females.

Exclusion criteria were as follows: receiving assistance or care covered by long-term care insurance in Japan, unable to perform the activities of daily living by themselves, frailty, severe neurological diseases (including dementia and cerebrovascular disease), medical contraindications to exercise, and a previous history of other severe health conditions. None of the participants had been instructed to implement dietary restrictions by a doctor. Measurements were conducted and surveys were completed over the course of several sessions at a university facility in Kitakyushu city in August and October 2016. Individual variables were assessed and surveyed on the same day by trained researchers, including registered dietitians, and health fitness programmers. This study conformed to the principles of the Declaration of Helsinki. The present study was approved by the Ethics Committee of the Elders College in the Council of Social Welfare, Kitakyushu City (approval No. 1601). All participants provided their written consent before the initiation of the present study.

Frailty assessment and physical function

Prefrailty was confirmed using the Japanese version of the Cardiovascular Health Study [27], which is a modified version of the Cardiovascular Health Study standards developed for the frailty phenotype proposed and validated by Fried *et al.* [28] that specifically screens for frailty in Japanese individuals. We categorized our participants into prefrailty (1–2 deficits) or non-frailty (0 deficits) groups using the following criteria: shrinking; weight loss ≥ 2 kg in the previous 6 mon; low activity; not partaking in moderate-level exercise or sports or low-level exercise for health reasons; exhaustion; unexplained fatigue in the past 2 weeks; weakness; grip strength of females < 18 kg; slowness; gait speed < 1.0 m/s [27].

A height/weight measurement device (AD-6350; A&D Co., Ltd., Tokyo, Japan) was used to simultaneously assess height and weight, and body mass index (BMI) was calculated based on the data obtained. Grip strength was evaluated as an index of muscle strength using the Smedley handheld dynamometer (Grip-D; Takei Ltd., Tokyo, Japan). Gait speed was assessed as follows. Markers were positioned at the start and end points of a 6-m walking route. To confirm that a usual walking pace was being evaluated, participants started to walk at least 2 m before the start point and finished walking at least 2 m after the end point. Gait speed was examined in one session and the distance walked per second (m/s) was analyzed. Before grip strength measurement, blood pressure and resting pulse were measured, and participants were informed that grip strength could not be measured if blood pressure was ≥ 180/110 mmHg or resting pulse rate was ≥ 110 or ≤ 50 beats per minute (HEM-7134, OMRON Corp., Kyoto, Japan).

Number of natural teeth and other variables

Participants completed self-administered questionnaires about the number of natural teeth (min–max, 0–28), functional teeth (min–max, 0–28), and the use of dentures. To confirm whether participants performed habitual exercise, they recorded the time spent partaking in habitual exercise in the previous week. They were also asked whether they lived with anyone, were current smokers, were being treated for chronic diseases and alcohol drinking habits.

Dietary assessment

Nutrient and food intakes were estimated and evaluated using the commercially available questionnaire, the validated Food Frequency Questionnaire (FFQ, Ver.5. 2016; Kenpakusha Co. Ltd., Tokyo, Japan) based on food groups [29]. This questionnaire has been widely used for the research in Japan [30,31]. Energy and nutrient intake levels were estimated using nutrient value estimation software (Excel Eiyou version 8.0; Kenpakusha Co. Ltd.) based on the 2015 version (7th rev.) of the standard tables of food composition in Japan [32]. Among the various diet variables examined, energy-adjusted intake, which was assessed by the method of residuals [33], was employed for daily nutrient and food intakes. Since there is currently no reliable composition table of dietary supplements available in Japan, the calculation of nutrient intakes in the present study did not include that from supplements.

Dietary pattern derivation

Dietary patterns of this studys' participants were derived in another previous our study [25]. A cluster analysis of large files (K-means) to evaluate the number of clusters was repeated at the time points indicated and the number of clusters was preliminarily set to 2-5 for the 20 food groups from the FFQ [29]. The numerical value of each variable in the final cluster center was evaluated and all clusters were characterized, with the most appropriate number of clusters being set to 3. The cluster analysis was performed using the corresponding application of SPSS Statistics. **Supplementary Table 1** shows the final cluster center values of 20 standardized food groups in the 3 most appropriate clusters. At the end of the analysis, a table of the clusters that individual participants belonged to and their Euclidean distances was displayed, thereby allowing us to clarify the number of participants in each of the 3 clusters. The 3 clusters of identified dietary patterns were descriptively named them as "vegetables and dairy products" (VD) (health-conscious diet) (n = 113), "rice and fish and shellfish" (RF) (traditional Japanese diet) (n = 100), and "bread and beverages" (BB) (favoriting soft food and beverages diet) (n = 54) patterns. Each pattern was characterized by high intakes of the following: the VD pattern, other vegetables and mushrooms, eggs, and dairy products; the RF pattern, rice, potatoes, fruits, algae, fish and shellfish, and meat other than those in the other 2 patterns; the BB pattern, bread, sugar and sweeteners, soy products, eggs, favorite beverages, and alcoholic beverages with a lack of animal products.

Sample size calculation

The sample size was calculated in advance by a power analysis to set the minimum sample size required for the statistical methods used in the present study. Due to the lack of relevant studies on older females in Japan, the effect size was set at 0.5 (medium effect size). Based on an α error of 0.05 and power (1-β error) of 0.80, the minimum total sample size was calculated, and the largest value of 159 was adopted [34,35]. Oversampling by 15% was performed to control for dropouts, resulting in a final minimum sample of 188 participants.

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Statistical analysis

The normality of data distribution was assessed using the Kolmogorov-Smirnov test. Participants were categorized into 2 groups according to the number of natural teeth: ≥ 20 teeth and < 20 teeth. The Mann-Whitney *U* test was used to examine differences in continuous variables, and Fisher's exact test or the chi-square test for categorical variables. Continuous variables are shown as medians (50th percentile) and categorical variables as percentages (%) and 95% confidence intervals (CI). The characteristics of participants classified into the 3 dietary patterns were compared. The distribution of data on the number of teeth, age, body height, body weight, BMI, and blood pressure were normally distributed between clusters, and analysis of variance was performed. The relationships among the number of natural teeth, prefrailty, and dietary patterns were investigated by a binomial logistic regression analysis using the forward-selection method with a likelihood ratio (criteria for selected variables: 0.05 to enter, 0.20 to remove). Spearman's correlation test was used to avoid multicollinearity effects and highly correlated variables were discarded (r > 0.7). The number of natural teeth negatively correlated with the use of dentures. The number of natural teeth ≥ 20 (0) and < 20 (1) groups was used as a dependent variables, and non-frailty/prefrailty and dietary patterns as independent variables. In model 2, age (yrs), and the number of chronic diseases (as continuous variables), living alone (yes or no), and alcohol drinking habits (yes or no) were set as adjusting variables. Finally, participants were divided into non-frailty and prefrailty groups, and differences in evaluation variables were analyzed. A binomial logistic regression analysis was performed using non-frailty (0)/prefrailty (1) as dependent variables and the number of natural teeth and dietary patterns as independent variables. In model 2, age (yrs, as continuous variable), living alone (yes or no), current smoker (yes or no), and alcohol drinking habits (yes or no) were set as adjusting variables. Statistical analyses were conducted using SPSS Statistics version 22.0 (IBM Corp., Armonk, NY, USA), and for binary logistic regression analysis, BellCurve for Excel version 4.05 (Social Survey Research Information Co. Ltd., Tokyo, Japan). All statistical analyses were 2-tailed, and statistical significance was set at P < 0.05.

RESULTS

Basic characteristics of participants

Data were analyzed for 267 community-dwelling older females aged 65–84 yrs who were prefrailty, and 4 frailty participants (1.5%) were excluded. **Table 1** describes the participants' demographic characteristics. Participants with natural teeth < 20 accounted for 57.3% of all participants. Prefrailty was 37.4%. Comparisons of the median values of both groups revealed that the number of natural teeth < 20 group was significantly older with significantly lower grip strength (kg) and gait speed (m/sec) (P < 0.001 each). In addition, the numbers of participants living alone and with an alcohol drinking habit were significantly higher in the number of natural teeth < 20 group (P = 0.001 and P = 0.003, respectively).

Classified according to 3 dietary patterns

Table 2 shows the characteristics of participants according to 3 dietary patterns. The VD pattern had the highest percentage of participants with natural teeth ≥ 20 at 52.2%. Furthermore, significant differences were observed in the mean number of natural teeth in the VD, RF, and BB patterns (22, 20, and 14, respectively; P < 0.001).

Table 1. Basic characteristics of participants classified according to the number of natural teeth

Characteristics	Overall (n = 267)	Number of natural teeth		*P*-value[3)]
		≥ 20 (n = 114, 42.7%)	< 20 (n = 153, 57.3%)	
Number of natural teeth	20 (17, 24)	25 (24, 27)	17 (13, 18)	< 0.001
Number of functional teeth	26 (24, 27)	25 (24, 27)	26 (25, 28)	0.092
Using denture, yes	52.4 (43.8–61.0)	2.6 (0.0–70.8)	89.5 (83.1–94.2)	< 0.001
Age (yrs)	73 (71, 76)	71 (68, 73)	75 (73, 78)	< 0.001
65–69	18.0 (8.3–31.8)	36.0 (21.5–52.5)	4.6 (0.0–41.0)	< 0.001
70–79	73.8 (67.1–79.8)	64.0 (51.9–75.0)	81.1 (73.0–87.5)	
80+	8.2 (0.6–28.8)	0	14.3 (3.1–36.1)	
Frailty criteria of the J-CHS				
Shrinking	0	0	0	-
Low activity	27.0 (17.1–38.8)	14.0 (1.8–40.8)	36.6 (24.0–50.6)	< 0.001
Exhaustion	12.4 (3.5–28.6)	2.6 (0.0–70.8)	19.6 (7.2–38.4)	< 0.001
Weakness[1)]	4.9 (0.0–33.0)	3.5 (0.0–60.2)	5.9 (0.0–42.4)	0.567
Slowness[2)]	7.9 (0.6–28.6)	2.6 (0.0–70.8)	13.1 (2.2–35.9)	< 0.001
Frailty				< 0.001
Non-frailty	62.6 (54.7–69.9)	85.1 (76.3–91.6)	45.8 (33.8–58.1)	
Prefrailty	37.4 (27.9–47.7)	14.9 (2.6–40.5)	54.2 (42.9–65.3)	
Dietary patterns				0.001
Vegetables and dairy products	42.3 (33.1–52.0)	51.8 (38.3–65.0)	35.3 (22.8–49.5)	
Rice and fish and shellfish	37.5 (27.9–47.7)	37.7 (23.3–53.9)	37.2 (24.7–51.1)	
Bread and beverages	20.2 (10.4–33.5)	10.5 (0.3–42.3)	27.5 (14.8–43.5)	
Grip strength (kg)	22.1 (19.8, 24.9)	24.2 (20.3, 25.4)	21.4 (19.4, 24.0)	< 0.001
Gait speed (m/sec)	1.30 (1.20, 1.49)	1.42 (1.27, 1.58)	1.26 (1.12, 1.35)	< 0.001
Exercise time (min/day)	35 (0, 70)	51 (20, 77)	25 (0, 55)	< 0.001
Body height (cm)	155.0 (150.0, 162.0)	155.8 (150.1, 163.0)	155.0 (150.0, 161.5)	0.453
Body weight (kg)	53.7 (48.5, 57.9)	52.9 (47.7, 60.7)	53.9 (49.5, 57.5)	0.610
Body mass index (kg/m^2)	21.9 (20.7, 23.8)	21.9 (20.3, 23.2)	21.9 (21.0, 23.8)	0.754
Systolic blood pressure (mmHg)	135 (126, 147)	133 (126, 146)	140 (124, 147)	0.255
Diastolic blood pressure (mmHg)	77 (73, 86)	77 (73, 82)	77 (72, 86)	0.576
Living alone, yes	19.9 (10.2–33.1)	8.8 (0.1–44.9)	28.1 (15.4–44.0)	0.001
Alcohol drinking, yes	40.5 (31.1–50.4)	29.8 (15.3–48.0)	48.4 (36.5–60.3)	0.003
Current smoker, yes	5.6 (0.0–32.1)	2.6 (0.0–70.8)	7.8 (0.0–39.9)	0.105
During dental treatment, yes	10.9 (2.3–28.3)	7.9 (0.0–45.7)	13.1 (2.2–35.9)	0.233
Number of chronic diseases				0.002
0	53.6 (45.0–62.0)	64.9 (52.9–75.7)	45.1 (33.1–57.6)	
≥ 1	46.4 (37.4–55.6)	35.1 (20.7–51.9)	54.9 (43.6–65.8)	

Values are median (interquartile range) or percentage of participants (95% confidence interval).
J-CHS, Japanese version of the Cardiovascular Health Study [27].
1)Weakness, grip strength < 18 kg [27].
2)Slowness, gait speed < 1.0 m/s [27].
3)For continuous variables, Mann-Whitney *U* test was used; for categorical variables, Fisher's exact test or chi-squared test was used to test differences.

Factors associated with tooth loss

Table 3 shows the results of the binomial logistic regression analysis of factors associated with the number of natural teeth. In adjusted model 2, participants with prefrailty were more likely to have natural teeth < 20 than those without (odds ratio [OR], 4.66; 95% CI, 2.54–8.52; $P < 0.001$). The VD pattern inversely correlated with natural teeth < 20 (OR, 0.43; 95% CI, 0.27–0.69; $P < 0.001$). There was no association between the number of natural teeth and RF pattern was in model 1; similarly, there was no significant association (OR: 0.71, 95% CI, 0.45–1.13; $P = 0.149$) in the adjusted model 2.

Since the number of natural teeth correlated with prefrailty, factors associated with prefrailty were also examined, as shown in **Table 4**. Participants with prefrailty were older ($P < 0.001$) and more likely to be current smokers ($P = 0.001$) than those with non-frailty. Additionally, the rate of having one or more chronic diseases under treatment was significantly higher ($P < 0.001$) in participants with prefrailty.

Table 2. Characteristics of participants classified according to three dietary patterns

Characteristics	Dietary pattern			
	Vegetables and dairy products (n = 113)	Rice and fish and shellfish (n = 100)	Bread and beverages (n = 54)	*P*-value[3)]
Number of natural teeth				0.001
≥ 20	52.2 (38.8–65.4)	43.0 (27.9–59.1)	22.2 (3.9–54.9)	
< 20	47.8 (33.9–61.9)	57.0 (43.2–70.1)	77.8 (62.1–89.3)	
Number of natural teeth	22 ± 5	20 ± 4	14 ± 7	< 0.001
Number of functional teeth	27 ± 2	25 ± 2	21 ± 5	< 0.001
Using denture, yes	47.8 (33.9–61.9)	56.0 (42.0–69.3)	55.6 (36.3–73.8)	0.428
Age (yrs)	73 ± 4	73 ± 4	76 ± 5	< 0.001
65–69	16.8 (3.6–41.2)	26.0 (9.8–46.5)	7.4 (0.0–60.2)	< 0.001
70–79	79.7 (69.8–87.5)	74.0 (62.4–83.6)	61.1 (42.5–77.7)	
80+	3.5 (0.0–60.2)	0	31.5 (11.2–58.4)	
Frailty criteria of the J-CHS				
Shrinking	0	0	0	-
Low activity	21.2 (7.6–42.8)	27.0 (11.7–47.7)	38.9 (18.5–62.6)	0.056
Exhaustion	10.6 (0.3–42.4)	8.0 (0.0–48.6)	24.1 (5.3–55.3)	0.012
Weakness[1)]	0	0	24.1 (5.3–55.3)	-
Slowness[2)]	3.5 (0.0–60.2)	0	31.4 (11.2–58.3)	-
Grip strength (kg)	22.3 ± 3.2	22.5 ± 2.6	21.4 ± 3.6	0.092
Gait speed (m/sec)	1.37 ± 0.24	1.41 ± 0.25	1.19 ± 0.28	< 0.001
Exercise time (min/day)	57 ± 56	39 ± 37	36 ± 35	0.004
Frailty				< 0.001
Non-frailty	69.9 (58.5–79.8)	73.0 (61.3–82.8)	27.8 (8.2–56.6)	
Prefrailty	30.1 (15.5–48.3)	27.0 (11.7–47.7)	72.2 (55.4–85.5)	
Body height (cm)	155.8 ± 6.6	156.5 ± 7.1	154.8 ± 6.3	0.308
Body weight (kg)	54.5 ± 7.8	53.1 ± 6.7	52.4 ± 6.9	0.147
Body mass index (kg/m^2)	22.4 ± 2.4	21.6 ± 2.0	21.8 ± 2.3	0.032
Systolic blood pressure (mmHg)	136 ± 18	135 ± 15	139 ± 18	0.384
Diastolic blood pressure (mmHg)	78 ± 11	78 ± 10	80 ± 13	0.467
Living alone, yes	16.8 (3.6–41.2)	18.0 (3.9–43.4)	29.6 (9.7–57.4)	0.128
Alcohol drinking, yes	38.1 (23.6–54.2)	28.0 (12.6–48.3)	68.5 (51.1–82.8)	< 0.001
Current smoker, yes	2.7 (0.0–70.8)	4.0 (0.0–60.2)	7.4 (0.0–60.2)	0.689
During dental treatment, yes	11.5 (0.3–42.5)	7.0 (0.0–41.0)	16.7 (1.2–54.4)	0.177
Number of chronic diseases				< 0.001
0	55.8 (42.6–68.3)	67.0 (54.4–78.0)	24.1 (5.3–55.3)	
≥ 1	44.2 (30.2–59.1)	33.0 (17.5–51.6)	75.9 (59.9–88.0)	

Values are mean ± SD or percentage of participants (95% confidence interval).
J-CHS, Japanese version of the Cardiovascular Health Study [27].
1)Weakness, grip strength < 18 kg [27].
2)Slowness, gait speed < 1.0 m/s [27].
3)For continuous variables, analysis of variance was used; for categorical variables, chi-square test was used to test differences across the dietary patterns.

Table 3. Logistic regression analysis of factors associated with the number of natural teeth

Independent variables	Model 1		Model 2	
	Crude OR		Adjusted[2)] OR	
	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
Frailty				
Non-frailty[1)] (Ref.)	1.00		1.00	
Prefrailty[1)]	6.18 (3.54–10.77)	< 0.001	4.66 (2.54–8.52)	< 0.001
Dietary patterns				
Bread and beverages[1)] (Ref.)	1.00		1.00	
Vegetables and dairy products[1)]	0.54 (0.36–0.83)	0.005	0.43 (0.27–0.69)	< 0.001
Rice and fish and shellfish[1)]	-	-	0.71 (0.45–1.13)	0.149

OR, odds ratio; CI, confidence interval.
1)Numbers of subjects. Total: 267, number of natural teeth ≥ 20, 114; number of natural teeth < 20, 153; non-frailty, 167; prefrailty, 100; bread and beverages, 54; vegetables and dairy products, 113; rice and fish and shellfish, 100.
2)Adjusted for age (yrs) and the number of chronic diseases as continuous variables (n = 267 each), living alone (yes: n = 53 or no: n = 214), and alcohol drinking (yes: n = 108 or no: n = 159).

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Table 4. Characteristics of participants categorized by frailty criteria of the J-CHS

Characteristics	Non-frailty (n = 167, 62.6%)	Prefrailty (n = 100, 37.4%)	*P*-value[3)]
Number of natural teeth			< 0.001
≥ 20	85.1 (76.3–91.6)	14.9 (2.6–40.5)	
< 20	45.8 (33.8–58.1)	54.2 (42.9–65.3)	
Number of natural teeth	22 (18, 26)	17 (12, 18)	< 0.001
Number of functional teeth	27 (25, 28)	25 (22, 26)	< 0.001
Using denture, yes	42.5 (30.8–54.9)	69.0 (56.7–80.0)	< 0.001
Age (yrs)	73 (69, 75)	75 (74, 79)	< 0.001
65–69	25.7 (13.6–41.4)	5.0 (0.0–52.2)	< 0.001
70–79	72.5 (63.6–80.2)	76.0 (64.8–85.1)	
80+	1.8 (0.0–70.8)	19.0 (4.8–43.5)	
Frailty criteria of the J-CHS			
Shrinking	0	0	-
Low activity	0	71.0 (60.1–82.0)	-
Exhaustion	0	33.0 (17.5–51.6)	-
Weaknessa[1)]	0	13.0 (1.0–43.3)	-
Slowness[2)]	0	21.0 (6.1–44.6)	-
Dietary patterns			< 0.001
Vegetables and dairy products	47.3 (35.9–58.9)	34.0 (18.7–52.3)	
Rice and fish and shellfish	43.7 (32.1–55.9)	27.0 (11.7–47.7)	
Bread and beverages	9.0 (0.2–36.3)	39.0 (23.7–56.0)	
Grip strength (kg)	23.4 (20.0, 25.4)	21.3 (19.4, 24.0)	0.002
Gait speed (m/sec)	1.39 (1.26, 1.53)	1.20 (1.06, 1.30)	< 0.001
Exercise time (min/day)	51 (29, 82)	0 (0, 15)	< 0.001
Body height (cm)	155.0 (150.0, 162.5)	155.5 (150.5, 160.5)	0.605
Body weight (kg)	52.6 (47.9, 58.4)	54.5 (49.5, 57.6)	0.588
Body mass index (kg/m^2)	21.9 (20.4, 23.4)	21.9 (21.2, 23.8)	0.754
Systolic blood pressure (mmHg)	135 (127, 147)	140 (119, 149)	0.793
Diastolic blood pressure (mmHg)	77 (74, 82)	78 (71, 89)	0.259
Living alone, yes	12.0 (1.5–35.0)	33.0 (17.5–51.6)	< 0.001
Alcohol drinking, yes	33.5 (21.4–47.5)	52.0 (37.7–66.1)	< 0.001
Current smoker, yes	1.8 (0.0–70.8)	12.0 (0.3–44.5)	0.001
During dental treatment, yes	8.4 (0.2–36.2)	15.0 (1.9–43.1)	0.106
Number of chronic diseases			< 0.001
0	64.1 (54.2–73.2)	36.0 (20.5–53.8)	
≥ 1	35.9 (23.9–49.4)	64.0 (51.0–75.7)	

Values are median (interquartile range) or percentage of participants (95% confidence interval).
J-CHS, Japanese version of the Cardiovascular Health Study [27].
1)Weakness, grip strength < 18 kg [27].
2)Slowness, gait speed < 1.0 m/s [27].
3)For continuous variables, Mann-Whitney *U* test was used; for categorical variables, Fisher's exact test or chi-squared test was used to test differences.

Table 5 shows the results of binomial logistic regression analysis of factors associated with prefrailty. Both VD and RF patterns were inversely correlated with prefrailty. The values for each pattern in adjusted model 2 were as follows: VD: OR, 0.38; 95% CI, 0.16–0.91; *P* = 0.029; and RF: OR, 0.26; 95% CI, 0.11–0.62; *P* = 0.003.

DISCUSSION

In this cross-sectional study involving 267 community-dwelling older females, we adopted 3 dietary patterns from our previous study [25] to examine the relationships among tooth loss, prefrailty, and dietary patterns. The self-reported number of natural teeth < 20 positively correlated with prefrailty and inversely correlated with the VD pattern (health-conscious diet). The OR of prefrailty was > 4-fold higher among older females with natural teeth < 20 than among those without. Moreover, the VD and RF (traditional Japanese diet) patterns

Table 5. Logistic regression analysis of factors associated with prefrailty according to frailty criteria of the J-CHS

Independent variables	Model 1		Model 2	
	Crude OR		Adjusted[2] OR	
	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
Number of natural teeth (continuous)[1]	0.88 (0.83–0.92)	< 0.001	0.85 (0.80–0.90)	< 0.001
Dietary patterns				
Bread and beverages[1] (Ref.)	1.00		1.00	
Vegetables and dairy products[1]	0.26 (0.11–0.63)	0.003	0.38 (0.16–0.91)	0.029
Rice and fish and shellfish[1]	0.21 (0.09–0.49)	< 0.001	0.26 (0.11–0.62)	0.003

J-CHS, Japanese version of the Cardiovascular Health Study [27]; OR, odds ratio; CI, confidence interval.
[1]Numbers of subjects. Total: 267, non-frailty, 167; prefrailty, 100; bread and beverages, 54; vegetables and dairy products, 113; rice and fish and shellfish, 100.
[2]Adjusted for age (yrs) as continuous variables (n = 267), living alone (yes: n = 53 or no: n = 214), current smoker (yes: n = 15 or no: n = 252), and alcohol drinking (yes: n = 108 or no: n = 159).

inversely correlated with prefrailty. The present results revealed that tooth loss may be associated with prefrailty, and showed that the VD pattern correlated with a lower risk of tooth loss. We also demonstrated that the VD and RF patterns both correlated with a lower risk of prefrailty. To the best of our knowledge, this is the first study in Japan to report relationships among tooth loss, prefrailty, and dietary patterns.

The prevalence of prefrailty was 37.4%, which is consistent with previously reported values of 47.0%, 33.6%, and 40.7% in studies on the relationship between tooth loss and prefrailty [36-38]. The relationship between a low number of teeth (≤ 20 teeth), with or without dentures [36], and prefrailty reported by Zhang *et al.* [36] supports the present results. On the other hand, Kang and Jung [37] and de Andrade *et al.* [38] found no correlation between the number of teeth and prefrailty. The former reported a relationship between chewing difficulty caused by a reduced number of teeth and prefrailty [37], while the latter noted that the need for dental prostheses increased the likelihood of prefrailty and frailty and also that a higher number of teeth was associated with a lower likelihood of frailty [38]. Regarding the relationship between tooth loss and frailty in consideration of conditions that may occur after tooth loss, the number of teeth has been proposed as an important factor associated with prefrailty and frailty, and this supports the hypothesis of the present study that a self-reported number of natural teeth < 20 is associated with prefrailty among community-dwelling older females.

Some of the most prevalent non-communicable diseases worldwide include dental caries, periodontal disease, and tooth loss, even though they are mostly preventable [39]. Tooth loss is more frequent in older adults [40]. Therefore, as a population approach in the preliminary stage of oral frailty, the maintenance of oral hygiene to reduce the risk of periodontitis and dental caries and the prevention of tooth loss are key points in the prefrailty and frailty pathways.

The present study revealed an inverse correlation between VD pattern, characterized by high vegetable and dairy intake, and natural teeth < 20. This result was partially similar to the conclusion of Ishimiya *et al.* [22] that scores for the dietary pattern characterized by high vegetable intake were low among individuals with tooth loss and reduced vegetable intake because they have difficulty eating vegetables, but are able to consume rice, sake, and beer. We previously reported that the mean number of natural teeth among participants with the BB pattern (favoring a soft foods and beverages diet) from cluster analysis was 14, which was significantly lower than those for other dietary patterns (**Table 2**). These participants were more likely to prefer soft foods and beverages due to tooth loss or other oral functional declines [25].

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The present study also showed that the VD and RF patterns both inversely correlated with prefrailty. Among the limited number of studies that examined the relationship between dietary patterns and prefrailty, that conducted by Bollwein *et al.* [18] using MED scores (maximum 9 points: the healthiest diet) and sex-specific medians as cut-off points is noteworthy. They reported that the mean MED score for frailty was significantly lower than those for prefrailty and non-frailty among older adults, whereas no significant differences were observed in the score between prefrailty and non-frailty [18]. Kim *et al.* [41] used reduced rank regression and reported that the "meat, fish, and vegetables" pattern inversely correlated with prefrailty and exhaustion, whereas the "milk" pattern did not correlate with any factor, indicating a low milk/dairy intake (mean: 52.9 g per day) as the cause. Previous studies demonstrated that daily milk/dairy intake may contribute to recovery and prevention of frailty [42-44]. Otsuka *et al.* [44] examined the relationship between dairy intake and progression to frailty among community residents with prefrailty, and found that milk and yogurt intake was associated with recovery from prefrailty. Furthermore, when focusing on the "meat, fish, and vegetables" pattern identified by Kim *et al.* [41], rice showed a factor loading of 0.24. Based on these findings, the present results serve as a nutritional strategy to prevent prefrailty.

There are a number of limitations that need to be addressed. The cross-sectional nature of the present study hinders the establishment of causal relationships. Data were collected at one specific time point, making it challenging to interpret the connections observed. To address this limitation, longitudinal or interventional studies are needed in the future. Furthermore, the utilization of self-reported information, such as the number of teeth and dietary status, may have affected the validity and accuracy of the results obtained. In addition, the study's recruitment of a particular group of participants restricts the applicability of the present results to other populations. Moreover, the cluster analysis employed to assess dietary patterns may be culturally specific and not easily transferable to other settings [45]. Another limitation is that the present study failed to consider significant variables, such as the presence or absence of periodontitis, the oral care status, and economic factors, which may contribute to tooth loss and play a role in the onset of frailty.

In conclusion, our findings suggest that maintaining a minimum of 20 natural teeth and continuing VD and RF dietary patterns are beneficial in promoting prevention of, and recovery from, prefrailty in the older. Our findings may be applicable to both healthy and prefrailty individuals. Causal association is yet to be elucidated due to the cross-sectional nature of the data; thus, it is important to understand how these factors affect each other. Future longitudinal studies are needed to address this hypothesis.

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SUPPLEMENTARY MATERIAL

Supplementary Table 1

Final cluster center values using a cluster analysis of large files (K-means)

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