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Association between dental status and food diversity among older Japanese

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Objective: To investigate the relationship of dental status to food diversity among older Japanese. ***Design and Setting:*** A community-based cross-sectional study conducted in the town of Tosa, Kochi Prefecture, Japan. ***Methods:*** The study participants were 252 Japanese (84 men and 168 women, average age 81.2 years) and dentate participants were classified into three groups: 1-9 teeth, 10-19 teeth and 20 or more teeth. Food diversity was assessed as a validated measure of dietary quality using the 11-item Food Diversity Score Kyoto (FDSK-11), which evaluates frequency of consumption of 11 main food groups. Multivariable analysis of the differences in FDSK-11 score ranging from 0 to 11, with a higher score indicating greater food diversity, among the three dental status groups was conducted using general linear models. All the performed analyses were stratified by gender. ***Results:*** There was no association between dental status and food diversity score in models for men. In contrast, women with ≤9 teeth and with 10-19 teeth had significantly lower FDSK-11 scores than women with ≥20 teeth after adjusting for confounders (p<0.001 and p=0.009, respectively). Additionally, there was a trend toward lower scores for FDSK-11 with fewer teeth (p=0.001). ***Conclusion:*** A less varied diet, as indicated by low FDSK-11 score, was observed in female participants with fewer teeth. Tooth loss was associated with poor diet quality among older Japanese women.

Key words*: epidemiology, aged, diet, food diversity, tooth loss, cross-sectional studies, Japan*

Introduction

Food diversity is an important dietary factor in dietary quality. Dietary variety has been found to be associated with energy intake, nutrient intake and biochemical measures of nutritional status in the elderly (Mirmiran *et al.*, 2006). The overall nutritional quality of the diet was improved with a diverse diet. Diversity in the diet is a simple tool for screening and identifying people at nutritional risk (Bernstein *et al.*, 2002). In addition, previous studies have reported that intake of a variety of foods is associated with lower risks of chronic diseases and mortality in elderly individuals (McCullough *et al.*, 2002; Michels and Wolk, 2002).

Decline in food intake is caused by multiple factors. Dental status is one of the main factors influencing food intake. Tooth loss has been associated with impaired chewing ability and may limit the type and quantity of food consumed. Individuals who are either edentulous or have fewer natural teeth tend to avoid hard food and prefer soft, easily chewed food (Krall *et al.*, 1998). Chewing ability has often been measured by questionnaires asking asked subjects about their perceived chewing difficulty with respect to certain foods (Inukai *et al.*, 2010). Food diversity measurement has a close correlation with such measures and in one method subjects report the frequency of their consumption of certain food groups (Kimura *et al.*, 2012; 2013).

Increasing age is another important risk factor for nutrition. Elderly people are at a greater risk of food insufficiency due to acute and chronic diseases, physiological change, financial and social status change and functional decline. Food intake decreases with aging, and can be accompanied by a large decline in dietary variety (Vellas *et al.*, 1997). Increasing age is an important risk factor for dental status as well. Tooth loss is typically associated with older adults. Growing awareness of the importance of oral health in the field of geriatric nutrition has been reported (Yoshihara *et al.*, 2005). Numerous studies have investigated the association of dental status with specific food, nutrient or energy intake among the elderly (Sheiham and Steele, 2001; Yoshihara *et al.*, 2005). However, epidemiologic data examining the relation between dental status and overall diet quality are sparse, especially in Asian populations. Further study is needed to clarify this association in Japanese, one of the fastest aging populations in the world. This study was therefore planned with the purpose of assessing whether dental status was related to food diversity among older Japanese.

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Materials and Methods

The current study used a cross-sectional design. In April 2010, all 960 individuals aged 75 years or more residing in the town of Tosa, Kochi Prefecture, Japan, except for 150 individuals living in hospitals or nursing homes, were sent a written request to participate in the geriatric health survey. Subsequently, 34.7% (*n*=333) responded positively to participation in the survey. In August 2010, study participants underwent dental examination, dietary assessment, interview and anthropometric evaluation at a community center. Sixty-three individuals did not submit complete data. Eighteen individuals were diagnosed with cognitive impairment, as assessed using Hasegawa's Dementia Scale-Revised with a score of ≤20 points, and were excluded from the analyses. Data were, therefore, available from 252 participants (84 men and 168 women, average age: 81.2 years). The sample-size calculation was based on Kimura's study on the effect of chewing ability on Food Diversity Score Kyoto (FDSK-11) score (Kimura *et al.*, 2013). The sample size to detect a difference at alpha level 0.05 (two sided, power 80%) with an effect size of 0.8 and standard deviation (sd) of 1.2 was estimated at 37 individuals per group.

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by The Ethical Committee of Faculty of Medicine, Kyoto University in Kyoto, Japan. Written informed consent was obtained from all study participants.

Two trained dentists (HO and TY), under sufficient illumination using artificial light, determined the number of teeth (excluding the third molar) and the use of dentures for each participant. All erupted permanent teeth except for remaining roots were counted as retained teeth. None of the study participants had dental implants. One trained dentist (TT) who did not know the participants' dental conditions assessed chewing ability using Masticatory Performance Evaluating Gum (XYLITOL, 70 mm × 20 mm × 1 mm, 3.0 g; Lotte, Saitama, Japan), which changes colour depending on chewing performance. The participants were asked to chew the gum as they usually chew foods. Immediately after they had chewed the gum for 2 min, the dentist checked the colour of the chewed gum using a five colour chart to assign the participant a score ranging from 1 to 5 (1, very poor; 2, poor; 3, moderate; 4, good; 5, very good chewing ability) (Kimura *et al.*, 2013). Individuals with removable dentures kept their dentures during the measurements. Before the examination, calibration was done at the Niigata University Medical & Dental Hospital. Intra-examiner reliability of gum (chewing) score was confirmed using percent agreement (91.2%). Subjective sense of chewing difficulty was also assessed by asking participants to respond "yes" or "no" to the question, "In the past 6 months, have you had difficulty chewing when you eat hard foods?" in an interview.

Food diversity was assessed as a measure of dietary quality using the 11-item FDSK-11 (Kimura *et al.*, 2013). This validated retrospective method of dietary diversity assessment evaluates frequency of consumption of 11 main food groups (grains, potatoes, beans and soybean products, meat, fish and shellfish, eggs, milk and dairy products, vegetables, seaweed, nuts and fruits). After the participants had rated their frequency of consumption of each group with a score of 1 (consumption once or more per week) or 0 (consumption less than once per week), the individual scores were summed to obtain a FDSK-11 score ranging from 0 to 11, with a higher score indicating greater food diversity. A more precise assessment of the frequency of food intake was carried out by asking the participants the question "How often do you eat these foods in a week?", using the same 11 food groups, to which they responded by assigning a score of 4 (every day), 3 (often or 3–5 days/week), 2 (sometimes or 1–2 days/week) or 1 (hardly ever) (Kimura *et al.*, 2013).

An interview was conducted on all participants including establishment of smoking status and drinking behaviour. Information about age, years of school attendance, medical diagnosis of diabetes and usage of prescription medications (antidepressants and antihypertensives) was also obtained in the interviews. Anthropometric evaluation included measurements of height and weight to calculate body mass index (BMI).

The principal exposure variable was defined based on the number of teeth present. Initially participants were divided in edentate and dentate. Dentate participants were further classified in three groups; 1-9 teeth, 10-19 teeth and 20 or more teeth.

FDSK-11 score and food frequency scores of FDSK-11 components were used for outcome variables. In the current study, the mean FDSK-11 score was 10.3 (min=4, max=11). Tests of normality using the Shapiro-Wilk statistic revealed that FDSK-11 score was not normally distributed; therefore, a $\log_{10}$ transformed variable was used to achieve a more symmetric distribution (pre-transformation, skewness -3.4, kurtosis 17.5; post-transformation, -2.5 and 10.2 respectively).

Analysis of variance for continuous variables [age, BMI and gum (chewing) score] and the Chi-square test for categorical variables (educational level, diabetes, medication use, smoking status, drinking behaviour, denture use and subjective sense of chewing difficulty) were used to test differences in the means and percentages of selected characteristics among the different study groups. Post-hoc tests were conducted using pairwise comparisons with Bonferonni's correction for continuous variables and pairwise comparisons of marginal linear predictions, which were calculated subsequent to the regression model, for categorical variables.

First, multivariable analysis of the differences in FDSK-11 score and food frequency scores of FDSK-11 components between edentate and dentate participants was conducted using general linear models. Multivariable models were adjusted for potential confounders: age (continuous), education (categories: school attendance: ≥9 or <9 years), smoking status (categories: never; former or current smoker), alcohol use (categories: never or rarely; sometimes, usually or always), BMI (continuous), diabetes (categories: yes or no) and medication use (categories: yes or no). Second, similar analyses were conducted among the three dental status groups (referent category: ≥20 teeth). These analyses were also adjusted for denture use (categories: yes or no). All the analyses were stratified by gender. Effect modification was evaluated by adding interaction terms between the main exposure and each of the third variables in the regression model. Interaction terms found to be statistically non-significant were not included in the model. Least square means (LSMs) of FDSK-11 score and food frequency scores of FDSK-11 components were obtained across categories of dental status. Tests for trend were performed by fitting the three-category dental status variables in their continuous form to the regression models.

All calculations and statistical analyses were performed using the statistical software package STATA v13 with the level of significance set at $\alpha=0.05$.

Results

Table 1 shows selected characteristics between edentate and dentate participants. Compared with male edentate participants, male dentate participants were younger and had higher gum (chewing) score ($p<0.05$). Compared with female edentate participants, female dentate participants were younger and had higher BMI, lower rate of diabetes and higher gum (chewing) score ($p<0.05$). Table 2 shows dentate participants' characteristics by number of remaining teeth category. Among men, significant differences were observed in denture use, gum (chewing) score and subjective sense of chewing difficulty. Higher percentages of denture use and subjective sense of chewing difficulty were found among men with fewer teeth ($p<0.05$). Men with ≤9 teeth had lower gum (chewing) score than men with ≥20 teeth ($p<0.05$). Among women, significant differences were observed in age, denture use, gum (chewing) score and subjective sense of chewing difficulty. Women with ≤9 teeth were older than women with ≥20 teeth ($p<0.05$). Higher percentages of denture use and subjective sense of chewing difficulty and lower gum (chewing) score were found among women with fewer teeth ($p<0.05$).

Table 3 shows the estimated LSMs of the FDSK-11 score and food frequency scores of FDSK-11 components by category of number of remaining teeth. The antilog of $\log_{10}$ values for LSMs of FDSK-11 score have been presented to provide interpretable results. There were no interactions of dental status with the covariates in either gender. There was no statistical association between dental status and food diversity score in models for men. In contrast, women with ≤9 teeth and with 10-19 teeth had significantly lower FDSK-11 scores than women with ≥20 teeth after adjusting for confounders ($p<0.001$ for ≤9 teeth and $p=0.009$ for 10-19 teeth). Women with ≤9 teeth had significantly lower food frequency scores for potatoes ($p=0.032$), fish and shellfish ($p=0.019$), vegetables ($p=0.031$), nuts ($p=0.003$) and fruits ($p=0.021$) than women with ≥20 teeth. Furthermore, there was a trend toward lower scores for FDSK-11 ($p_{trend}<0.001$), as well as frequencies for potatoes ($p_{trend}=0.019$), meat ($p_{trend}=0.041$), fish and shellfish ($p_{trend}=0.004$), vegetables ($p_{trend}=0.009$), nuts ($p_{trend}=0.001$) and fruit ($p_{trend}=0.005$) consumption with fewer teeth.

On the other hand, there were no statistical differences in FDSK-11 score and its components between edentate and dentate participants of either gender (data not shown).

Table 1. Selected characteristics between edentate and dentate participants

Men	*Overall* *n*=84	*Dentate* *n*=58	*Edentate* *n*=26	*p*
Age and educational level				
Age, mean (sd)	80.7 (4.2)	**80.1 (3.7)**	**82.1 (4.8)**	**0.038**
School attendance <9 years, *n* (%)	35 (41.7)	23 (39.7)	12 (46.2)	0.576
Health status and health behaviour				
BMI (kg/m^2), mean (sd)	22.7 (2.7)	22.9 (2.7)	22.4 (2.5)	0.500
Diabetes, *n* (%)	10 (11.9)	8 (13.8)	2 (7.7)	0.425
Medication intake, *n* (%)	39 (46.4)	29 (50.0)	10 (38.5)	0.327
Smoking status, *n* (%)				
Never smoked	44 (52.4)	31 (53.5)	13 (50.0)	0.770
Previous or current smoker	40 (47.6)	27 (46.5)	13 (50.0)	
Drinking behaviour, *n* (%)				
Never or rarely	39 (46.4)	25 (43.1)	14 (53.9)	0.361
Sometimes, usually or always	45 (53.6)	33 (56.9)	12 (46.1)	
Oral health status				
Gum score (range 1 to 5), mean (sd)	3.6 (0.9)	**3.8 (0.8)**	**3.1 (1.0)**	**0.001**
Subjective sense of chewing difficulty†, *n* (%)	27 (32.1)	18 (31.0)	9 (34.6)	0.745
Women	*Overall* *n*=168	*Dentate* *n*=110	*Edentate* *n*=58	*p*
Age and educational level				
Age, mean (sd)	81.5 (4.7)	**80.7 (4.6)**	**83.0 (4.6)**	**0.002**
School attendance <9 years , *n* (%)	82 (48.8)	55 (50.0)	27 (46.6)	0.671
Health status and health behaviour				
BMI (kg/m^2), mean (sd)	22.9 (3.4)	**23.4 (3.4)**	**22.1 (3.4)**	**0.020**
Diabetes, *n* (%)	24 (14.3)	**11 (10.0)**	**13 (22.4)**	**0.029**
Medication intake, *n* (%)	117 (69.6)	77 (70.0)	40 (69.0)	0.890
Smoking status, *n* (%)				
Never smoked	134 (79.8)	90 (81.8)	44 (75.9)	0.361
Previous or current smoker	34 (20.2)	20 (18.2)	14 (24.1)	
Drinking behaviour, *n* (%)				
Never or rarely	112 (66.7)	76 (69.1)	36 (62.1)	0.359
Sometimes, usually or always	56 (33.3)	34 (30.9)	22 (37.9)	
Oral health status				
Gum score (range 1 to 5), mean (sd)	3.4 (0.9)	**3.6 (0.8)**	**3.0 (0.9)**	**<0.001**
Subjective sense of chewing difficulty†, *n* (%)	68 (40.5)	45 (40.9)	23 (39.7)	0.875

sd=standard deviation, BMI=body mass index.
†Responded "Yes" to the question "In the past 6 months, have you had difficulty chewing when you eat hard foods?"

Table 2. Selected characteristics of dentate participants by number of remaining teeth categories by gender

Men	*≥20 Teeth* *n*=24	*10-19 Teeth* *n*=19	*1-9 Teeth* *n*=15	*p*
Age and educational level				
Age, mean (sd)	78.9 (2.8)	80.7 (4.1)	81.1 (4.2)	0.127
School attendance years <9 years, *n* (%)	12 (50.0)	5 (26.3)	6 (40.0)	0.288
Health status and health behaviour				
BMI (kg/m^2), mean (sd)	22.9 (2.7)	22.5 (2.1)	23.3 (3.5)	0.674
Diabetes, *n* (%)	4 (16.7)	2 (10.5)	2 (13.3)	0.844
Medication intake, *n* (%)	15 (62.5)	7 (36.8)	7 (46.7)	0.237
Smoking status, *n* (%)				
Never smoked	16 (66.7)	9 (47.4)	6 (40.0)	0.217
Previous & current smoker	8 (33.3)	10 (52.6)	9 (60.0)	
Drinking behaviour, *n* (%)				
Never or rarely	12 (50.0)	5 (26.3)	8 (53.3)	0.193
Sometimes, usually or always	12 (50.0)	14 (73.7)	7 (46.7)	
Oral health status				
Denture use†, *n* (%)	**3 (12.5)[a]**	**12 (63.2)[b]**	**14 (93.3)[b]**	**<0.001**
Gum score (range 1 to 5), mean (sd)	**4.0 (0.7)[a]**	**3.8 (0.4)**	**3.3 (1.0)[b]**	**0.026**
Subjective sense of chewing difficulty‡, *n* (%)	**3 (12.5)[a]**	**5 (26.3)[a]**	**10 (66.7)[b]**	**0.002**

Women	*≥20 Teeth* *n*=36	*10-19 Teeth* *n*=33	*1-9 Teeth* *n*=41	*p*
Age and educational level				
Age, mean (sd)	**79.4 (4.1)[a]**	**80.2 (4.1)**	**82.3 (5.0)[b]**	**0.014**
School attendance years <9 years, *n* (%)	13 (36.1)	18 (54.6)	24 (58.5)	0.120
Health status and health behaviour				
BMI (kg/m^2), mean (sd)	24.1 (3.2)	22.7 (3.2)	23.3 (3.5)	0.192
Diabetes, *n* (%)	4 (11.1)	5 (15.2)	2 (4.9)	0.330
Medication intake, *n* (%)	27 (75.0)	25 (75.8)	25 (61.0)	0.281
Smoking status, *n* (%)				
Never smoked	29 (80.6)	28 (84.9)	33 (80.5)	0.865
Previous or current smoker	7 (19.4)	5 (15.1)	8 (19.5)	
Drinking behaviour, *n* (%)				
Never or rarely	25 (69.4)	23 (69.7)	28 (68.3)	0.990
Sometimes, usually or always	11 (30.6)	10 (30.3)	13 (31.7)	
Oral health status				
Denture use†, *n* (%)	**9 (25.0)[a]**	**31 (93.9)[b]**	**39 (95.1)[b]**	**<0.001**
Gum score (range 1 to 5), mean (sd)	**4.2 (0.4)[a]**	**3.6 (0.9)[b]**	**3.1 (0.8)[c]**	**<0.001**
Subjective sense of chewing difficulty‡, *n* (%)	**6 (16.7)[a]**	**14 (42.4)[b]**	**25 (61.0)[b]**	**<0.001**

[a-c]Values in a row without a common superscript letter significantly differ as detected by multiple comparison tests.
sd=standard deviation, BMI=body mass index.
†Wearing dentures (either partial or complete).
‡Responded "Yes" to the question "In the past 6 months, have you had difficulty chewing when you eat hard foods?"

Discussion

To the best of our knowledge, this is the first study in Japan to investigate the association between dental status and food diversity among the older adults. Significantly lower FDSK-11 score was observed in female participants with fewer teeth after controlling for other important characteristics in the multivariable analysis. Low FDSK-11 score can suggest that dietary quality is deteriorating, being unbalanced and less varied (Kimura *et al.*, 2012). This seems to be partly attributable to the low frequency of multiple food group intake by women with fewer teeth. There was a trend toward lower intake frequency for potatoes, meat, fish and shellfish, vegetables, nuts and fruit with fewer teeth. A previous study demonstrated that slight (less than 0.5) differences in FDSK-11 score were significantly associated with depression symptoms among older Japanese (Kimura *et al.*, 2012). FDSK-11 score may be an acute marker for not only food diversity but also geriatric functions such as depression.

A previous study has indicated that dental status is associated with overall diet quality among U.S. populations. Sahyoun *et al*. (2003) investigated the associations between the number of posterior occlusal pairs of teeth and the Healthy Eating Index (HEI) score among the adults aged 50 years and over participating in the third National Health and Nutrition Examination Survey (NHANES III). HEI is a measure of overall quality of an individual's diet. HEI is scored according to the consumed number of servings of each of the five food groups (grain, fruit, vegetable, meat, and dairy), the percentage of calories from fat and saturated fat, the consumed amount of cholesterol and sodium, and a measure of dietary variety. Compared with individuals with five to eight posterior occluding pairs, those with fewer pairs remaining had consistently lower HEI scores. Our results provide evidence that the

Table 3. Associations between number of remaining teeth and food diversity score among dentate participants by gender†

Men	*≥20 Teeth (Referent) n=24*		*10-19 Teeth n=19*			*1-9 Teeth n=15*			
	LSM	*95% CI*	*LSM*	*95% CI*	*p*‡	*LSM*	*95% CI*	*p*‡	*p for trend*
Food frequency scores of FDSK-11 components									
Grains	4.0	3.7, 4.2	3.9	3.6, 4.1	0.566	3.8	3.5, 4.1	0.495	0.492
Potatoes	2.3	2.0, 2.6	2.1	1.9, 2.4	0.390	2.5	2.2, 2.9	0.508	0.501
Beans and soybean products	3.4	3.0, 3.7	3.1	2.8, 3.4	0.345	3.1	2.7, 3.5	0.333	0.332
Meat	2.4	2.1, 2.8	2.8	2.4, 3.1	0.282	2.6	2.2, 3.1	0.584	0.592
Fish and shellfish	2.8	2.4, 3.2	2.9	2.5, 3.3	0.783	3.0	2.5, 3.5	0.600	0.596
Egg	3.1	2.7, 3.5	2.7	2.3, 3.1	0.137	3.1	2.6, 3.6	0.952	0.933
Milk and dairy products	2.8	2.2, 3.4	2.3	1.8, 2.9	0.243	3.3	2.6, 4.0	0.353	0.356
Vegetables	3.4	3.1, 3.8	3.3	2.9, 3.6	0.572	3.6	3.2, 4.1	0.588	0.578
Seaweed	2.9	2.5, 3.3	2.4	2.0, 2.8	0.113	2.9	2.4, 3.4	0.937	0.917
Nuts	1.9	1.6, 2.2	2.0	1.7, 2.3	0.698	2.2	1.8, 2.5	0.382	0.376
Fruits	2.6	2.2, 3.1	2.9	2.4, 3.3	0.479	3.0	2.5, 3.6	0.280	0.276
FDSK-11§	10.5	10.0, 11.0	10.0	9.5, 10.5	0.226	11.0	10.3, 11.7	0.281	0.288
Women	*≥20 Teeth (Referent) n=36*		*10-19 Teeth n=33*			*1-9 Teeth n=41*			
	LSM	*95% CI*	*LSM*	*95% CI*	*p*‡	*LSM*	*95% CI*	*p*‡	*p for trend*
Food frequency scores of FDSK-11 components									
Grains	3.9	3.6, 4.1	4.0	3.7, 4.3	0.574	3.7	3.4, 3.9	0.285	0.120
Potatoes	2.5	2.2, 2.8	2.3	2.0, 2.7	0.406	**2.0**	**1.7, 2.3**	**0.032**	**0.019**
Beans and soybean products	3.3	3.0, 3.6	3.5	3.1, 3.8	0.502	3.2	2.8, 3.5	0.578	0.334
Meat	2.7	2.4, 3.0	2.6	2.2, 2.9	0.670	2.2	1.9, 2.6	0.076	**0.041**
Fish and shellfish	3.1	2.8, 3.4	3.1	2.8, 3.5	0.959	**2.5**	**2.2, 2.9**	**0.019**	**0.004**
Egg	3.0	2.7, 3.4	2.9	2.5, 3.4	0.770	3.1	2.6, 3.5	0.915	0.799
Milk and dairy products	3.0	2.6, 3.5	3.3	2.7, 3.8	0.525	2.7	2.2, 3.3	0.450	0.230
Vegetables	3.8	3.6, 4.0	3.8	3.5, 4.0	0.853	**3.4**	**3.1, 3.6**	**0.031**	**0.009**
Seaweed	2.8	2.5, 3.2	2.9	2.6, 3.3	0.694	2.7	2.4, 3.1	0.701	0.520
Nuts	2.5	2.2, 2.8	2.3	1.9, 2.6	0.337	**1.7**	**1.3, 2.1**	**0.003**	**0.001**
Fruits	3.2	2.9, 3.6	3.2	2.8, 3.6	0.914	**2.6**	**2.2, 3.0**	**0.021**	**0.005**
FDSK-11§	11.0	10.4, 11.8	**9.7**	**9.0, 10.4**	**0.009**	**9.0**	**8.3, 9.6**	**<0.001**	**<0.001**

FDSK-11=11-item Food Diversity Score Kyoto, LSM=least square mean, CI=confidence interval.
†Adjusted for age, education, smoking status, alcohol use, body mass index, diabetes, medication use and denture use.
‡Comparison with referent category.
§The antilog of log_{10} values for LSM have been presented to provide interpretable results.
Bold text highlights statistically significant findings ($p<0.05$).

association between dental status and diet quality also exists in a Japanese population.

In our study, chewing ability was poorer among participants with fewer teeth on the basis of both objective and subjective assessments. Participants with fewer teeth had lower gum (chewing) scores and higher percentage of self-perceived chewing problems. These findings are consistent with findings from previous work showing the association between number of teeth and percentages of individuals reporting chewing difficulty (Foerster *et al.*, 1998). Our study results suggested that oral functional limitations associated with tooth loss might lead to avoidance of certain foods, such as potatoes, meat, fish and shellfish, vegetables, nuts and fruit, which can lead to decreased dietary diversity among older Japanese women.

In the current study, chewing ability was assessed using specifically designed gum. On the other hand, questionnaires are often used to assess the subject's perceived chewing ability. Inukai *et al*. used a questionnaire to assess perceived chewing ability of 489 dentate individuals (mean age=63). The questionnaire encompassed 20 food items selected from 100 common Japanese foods, scoring each as either easy (1) or difficult (0) to chew each food and summing to give a chewing function score ranging 0 to 20 with higher scores indicating better chewing ability. They found that chewing function score was associated with oral health-related quality of life (Inukai *et al.*, 2010). It seems that FDSK-11 and chewing function scores have a close correlation. Future investigation of the association between these two outcome measures may be of interest.

Our findings suggest that oral health status can influence individual's food choice and food diversity; However, it is important to note that there are several factors other than oral health status that influence food choice, such as food preferences, dietary habits, nutritional knowledge, cooking skills and available food sources as well as psychosocial factors (Sahyoun *et al.*, 2003). The current study does not include data to address such factors; consequently we could not include them in the analyses. There was gender difference in such factors. There are three potential explanations for the gender difference in the association between dental status and

FDSK-11 score. First, generally, older men cook less frequently and have poorer cooking skills and lower motivation to change their eating habits than older women (Hughes *et al.*, 2004). This suggested that older men seldom change their diet, which appeared to negate the association between dental status and food diversity among male participants. The second explanation is the sample size limitation in men. Third, female dentate participants tended to have fewer natural teeth than male dentate participants in this study (mean=13.7, sd=8.3 vs. mean=16.3, sd=9.0, respectively; p=0.067). Earlier research demonstrated that tooth loss and poor chewing ability were associated with depression (Kimura *et al.*, 2013). Symptom of depression, which is a significant risk factor for dietary diversity decline (Kimura *et al.*, 2012), is more common in women than men (Lopez *et al.*, 2006). Therefore, it was assumed that older women were more prone to a decrease in food diversity due to tooth loss and depression.

No differences in FDSK-11 score and its components were observed between edentate and dentate participants of either gender. This was partly explained by the fact that the dentate group included a variety of dental conditions, ranging from fully dentate to almost edentulous, resulting in underestimation of the association between dental status and food diversity. Dentate and edentulous individuals should be analysed separately. The current study demonstrated that the number of retained teeth was an important factor for food diversity among dentate female individuals. Future studies are needed to explore the factors that influence individuals' food diversity among edentulous people. Denture status can be one of such factors. However, detailed data on removable dentures were not collected in our study; therefore, we could not assess the effects of denture use in detail, such as denture type, denture fit and denture location using the current data set.

We used 20 or more teeth as the referent category. It has been demonstrated that individuals with 20 or more remaining teeth had high scores for bite forces and masticatory abilities and could eat most types of Japanese foods (Tatematsu *et al.*, 2004). Based on this background, 8020 campaign, a national oral-health campaign led by the Japanese Ministry of Health, Labor and Welfare, was started in 1989 to promote oral health in Japan (Mizuno *et al.*, 1993). The objective of the campaign is to encourage people to retain 20 or more natural teeth at 80 years of age.

Although this study provides a novel finding that an association between dental status and food diversity was observed in this Asian (Japanese) older population, there is a potential risk that our final sample analysed may not be representative of the target study population, community-based older Japanese. Only 252 participants of the 960 individuals aged ≥75 years currently residing in the town of Tosa in 2010 were analysed. Because there was no information on the food diversity and dental health of the older general population in the town of Tosa, we could not compare the characteristics between the current study population and the general population. The mean number of teeth present was 9.8 (sd=10.0), and the percentage of participants with a subjective sense of chewing difficulty was 37.7% among the study participants. In the national dental survey, mean number of teeth present in adults aged ≥80 years was 11.1 (The Ministry of Health, Labour, and Welfare, 2011). The percentage of subjects with a subjective sense of chewing difficulty was reported to be 38.2% in a representative sample aged 75-84 years of a local city in Japan (Sendai City Government, 2010). Although, no great gap was observed in dental characteristics between the study population and these samples, it can be assumed that those who declined to participate in our survey or who did not submit complete data might be more likely to be less concerned with their diet and overall health. In this context, the results based on this single study should be interpreted with some caution, because selection bias may lead to over- or underestimation of the true association. There are several other limitations to the present study. First, our study had a cross-sectional design, which prevented us from assessing a temporal relationship and establishing causality. Second, the determination of the gum colour graduation and the assigning of a score of chewing ability between 1 and 5 were carried out by single dentist using a colour chart rather than by a machine. Although a strong correlation was found between the scores from the colour chart and measurements by the machine (Kamiyama *et al.*, 2010), it is unclear whether the human eye can judge the extent of colour graduation as accurately as a machine. Nevertheless, the use of only one dentist to carry out the colour discrimination process should increase the amount of consistency among the results of the process. Third, information on participants' systemic and oral health problems (e.g. stroke, dry mouth and swallowing difficulties), health, type and location of the teeth and income was not collected; a number of other potentially important confounders could not be included in the analyses. Residual confounding remains a risk. Future work with a larger, more diverse sample and more complete information would be necessary to substantiate our findings.

Conclusion

The presence of fewer teeth was associated with lower food diversity, as indicated by lower FDSK-11 score, in community-dwelling Japanese older women. Tooth loss can have a negative impact on dietary quality.

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References

Bernstein, M.A., Tucker, K.L., Ryan, N.D., O'Neill, E.F., Clements, K.M., Nelson, M.E., Evans, W.J. and Singh, M.A.F. (2002): Higher dietary variety is associated with better nutritional status in frail elderly people. *Journal of the American Dietetic Association* **102**, 1096-1104.

Foerster, U., Gilbert, G.H. and Duncan, R.P. (1998): Oral functional limitation among dentate adults. *Journal of Public Health Dentistry* **58**, 202-209.

Hughes, G., Bennett, K.M. and Hetherington, M.M. (2004): Old and alone: barriers to healthy eating in older men living on their own. *Appetite* **43**, 269-276.

Inukai, M., John, M.T., Igarashi, Y. and Baba, K. (2010): Association between perceived chewing ability and oral health-related quality of life in partially dentate patients. *Health and Quality of Life Outcomes* **19**, 118.

Kamiyama, M., Kanazawa, M., Fujinami, Y. and Minakuchi, S. (2010): Validity and reliability of a Self-Implementable method to evaluate masticatory performance: use of color-changeable chewing gum and a color scale. *Journal of Prosthodontic Research* **54**, 24-28.

Kimura, Y., Ogawa, H., Yoshihara, A., Yamaga, T., Takiguchi, T., Wada, T., Sakamoto, R., Ishimoto, Y., Fukutomi, E., Chen, W., Fujisawa, M., Okumiya, K., Otsuka, K., Miyazaki, H. and Matsubayashi, K. (2013): Evaluation of chewing ability and its relationship with activities of daily living, depression, cognitive status and food intake in the community-dwelling elderly. *Geriatrics & Gerontology International* **13**, 718-725.

Kimura, Y., Wada, T., Okumiya, K., Ishimoto, Y., Fukutomi, E., Kasahara, Y., Chen, W., Sakamoto, R., Fujisawa, M., Otsuka, K. and Matsubayashi, K. (2012): Eating alone among community-dwelling Japanese elderly: association with depression and food diversity. *Journal of Nutrition Health and Aging* **16**, 728-731.

Krall, E., Hayes, C. and Garcia, R. (1998): How dentition status and masticatory function affect nutrient intake. *Journal of the American Dental Association* **129**, 1261-1269.

Lopez, A.D., Mathers, C.D., Ezzati, M., Jamison, D.T. and Murray, C.J. (2006): Global and regional burden of disease and risk factors, 2001: systematic analysis of population health data. *Lancet* **367**, 1747-1757.

McCullough, M.L., Feskanich, D., Stampfer, M.J., Giovannucci, E.L., Rimm, E.B., Hu, F.B., Spiegelman, D., Hunter, D.J., Colditz, G.A. and Willett, W.C. (2002): Diet quality and major chronic disease risk in men and women: moving toward improved dietary guidance. *American Journal of Clinical Nutrition* **76**, 1261-1271.

Michels, K.B. and Wolk, A. (2002): A prospective study of variety of healthy foods and mortality in women. *International Journal of Epidemiology* **31**, 847-854.

The Ministry of Health, Labour, and Welfare. (2011): [Survey of Dental Diseases, 2011]. www.mhlw.go.jp/toukei/list/62-23.html

Mirmiran, P., Azadbakht, L. and Azizi, F. (2006): Dietary diversity within food groups: an indicator of specific nutrient adequacy in Tehranian women. *Journal of the American College of Nutrition* **25**, 354-361.

Mizuno, T., Nakagaki, H., Murakami, T., Kato, K., Tsuboi, S., Takigawa, T., Ozawa, A., Kumeno, C. and Ohno, Y. (1993): Lifestyles related to preserving 20 or more teeth at 80 years of age. *Nihon Koshu Eisei Zasshi* **40**, 189-195.

Sahyoun, N.R., Lin, C.L. and Krall, E. (2003): Nutritional status of the older adult is associated with dentition status. *Journal of the American Dietetic Association* **103**, 61-66.

Sendai City Government. (2010): [*A report of the Sendai 8020 survey*]. www.city.sendai.jp/kenko/__icsFiles/afieldfile/2011/04/26/21_8020.pdf

Sheiham, A. and Steele, J. (2001): Does the condition of the mouth and teeth affect the ability to eat certain foods, nutrient and dietary intake and nutritional status amongst older people? *Public Health Nutrition* **4**, 797-803.

Tatematsu, M., Mori, T., Kawaguchi, T., Takeuchi, K., Hattori, M., Morita, I., Nakagaki, H., Kato, K., Murakami, T., Tuboi, S., Hayashizaki, J., Murakami, H., Yamamoto, M. and Ito, Y. (2004): Masticatory performance in 80-year-old individuals. *Gerodontology* **21**, 112-119.

Vellas, B.J., Hunt, W.C., Romero, L.J., Koehler, K.M., Baumgartner, R.N. and Garry, P.J. (1997): Changes in nutritional status and patterns of morbidity among free-living elderly persons: A 10-year longitudinal study. *Nutrition* **13**, 515-519.

Yoshihara, A., Watanabe, R., Nishimuta, M., Hanada, N. and Miyazaki, H. (2005): The relationship between dietary intake and the number of teeth in elderly Japanese subjects. *Gerodontology* **22**, 211-218.