THE GERONTOLOGICAL SOCIETY OF AMERICA®

Journals of Gerontology: Medical Sciences
cite as: *J Gerontol A Biol Sci Med Sci*, 2015, Vol. 70, No. 12, 1548–1554
doi:10.1093/gerona/glv116
Advance Access publication September 3, 2015

OXFORD

Research Article

Association of Tooth Loss With Development of Swallowing Problems in Community-Dwelling Independent Elderly Population: The Fujiwara-kyo Study

Nozomi Okamoto,[1] Masayuki Morikawa,[2,3] Motokazu Yanagi,[4] Nobuko Amano,[4] Kimiko Tomioka,[1] Kan Hazaki,[5] Akihiro Harano,[6] and Norio Kurumatani[1]

[1]Department of Community Health and Epidemiology, Nara Medical University, Nara, Japan. [2]Department of Psychiatry, Mie Prefectural Mental Care Center, Mie, Japan. [3]Department of Psychiatry, Nara Medical University, Nara, Japan. [4]Department of Food and Nutrition, Tezukayama University, Nara, Japan. [5]Department of Physical Therapy, Osaka Electro-Communication University, Osaka, Japan. [6]Department of Orthopedics, Yamato Takada Municipal Hospital, Nara, Japan.

Address correspondence to: Nozomi Okamoto, DDS, PhD, Department of Community Health and Epidemiology, Nara Medical University, Nara, Japan. Email: onozomi@naramed-u.ac.jp

Received September 3, 2014; Accepted June 22, 2015

Decision Editor: Stephen Kritchevsky, PhD

Abstract

Background: Tooth loss induces changes to the anatomy of the oral cavity. We hypothesized that tooth loss may disturb smooth swallowing in healthy elderly people. The purpose of this study was to investigate the effect of tooth loss on the development of swallowing problems in an independent elderly population.

Methods: This was a 5-year prospective cohort study conducted in Nara, Japan. Included in this analysis were 1,988 community residents aged 65 years or older without swallowing problems at baseline. The participants were classified into quartile groups according to the number of remaining teeth at the baseline survey: 0–12, 13–22, 23–26, and 27–32 teeth. A decrease in the number of teeth during the survey was calculated by subtracting follow-up number from baseline number. Main outcome was the development of swallowing problems at follow-up.

Results: During follow-up, 312 individuals developed swallowing problems. After adjustment for confounding factors by multiple logistic regression analysis, the odds ratios for developing swallowing problems in participants with 13–22 or 0–12 teeth were 2.42 (95% confidence interval [CI], 1.61–3.63) and 2.49 (95% CI, 1.68–3.69), respectively, compared to participants with 27–32 teeth, demonstrating a significant relationship. The odds ratio of per 1 tooth decrease over 5 years was 1.08 (95% CI, 1.02–1.13), showing a significant association.

Conclusions: Swallowing problems due to aging are more likely to develop in individuals with fewer teeth.

Key Words: Epidemiology—Swallowing—Dysphagia—Tooth loss—Community-based

Swallowing problems are found in 25%–80% of individuals with stroke (1) and in 30%–70% of individuals with Parkinson's disease (2). Swallowing problems in elderly adults are the specific result of a pathological condition or illness (3). Ligamentous laxity, geniohyoid muscle atrophy, reduced muscle tone in the pharynx and esophagus, increased duration of swallowing, decreased maximum lingual isometric pressure, and increased swallow apnea are recognized as age-related physiological changes (4–9). These age-related changes may be negligible compared with the changes in swallowing related to degenerative neurologic diseases. However, endoscopic analysis revealed that laryngeal penetration and aspiration were observed in 11.3% and 6.5% of all swallows, respectively, in healthy elderly persons (10). Twenty percent of healthy elderly individuals showed high laryngeal penetration into the laryngeal vestibule during videofluoroscopy examination (11). We also found that swallowing problems were prevalent in up to 15% of independent living elderly individuals in an examination using a self-administered questionnaire and the 30-mL water swallow test (12). Therefore, it is necessary to investigate modifiable risk factors that are involved in swallowing function in elderly people living independently.

Swallowing can take place when food particles are small enough and sufficiently moistened with saliva (13). The main cause of poor masticatory ability is a reduction in the number of remaining teeth in healthy elderly people. Losing teeth induces changes to the anatomy of the oral cavity; therefore, we hypothesized that tooth loss may disturb smooth swallowing in healthy elderly people. To date, only a few studies have examined the relationship between tooth loss and swallowing function; thus, the purpose of this prospective cohort study was to investigate this relationship in an independent elderly population.

Methods

Selection of Subjects

This study was approved by the Ethics Committee of Nara Medical University. We used data from the baseline (in 2007 and the beginning of 2008) and follow-up (in 2012) examinations of the Fujiwara-kyo study (14–19). Written informed consent was obtained from each individual prior to their participation in the baseline and follow-up examinations. The Fujiwara-kyo study is an ongoing cohort study of volunteer men and women who, at baseline, were independent elderly residents of Nara Prefecture aged 65 years or older and able to walk unassisted.

Among the 4,206 persons who participated in the baseline examination, 3,109 individuals without swallowing problems at baseline were enrolled in the current study. By the time of the 2012 follow-up examination, 131 had died, 32 had moved away, 13 had been admitted to an institution, 233 were hospitalized or were receiving medical treatment, and 652 were nonresponders. Thus, there were 2,048 participants in the follow-up examination (65.9%, 2,048/3,109). To assess age-related swallowing problems, individuals who reported a history of cerebrovascular disease (n = 45), Parkinson's disease (n = 3), facial paralysis (n = 1), or parathyroid tumor (n = 1) during the follow-up period were excluded because these diseases sometimes have an influence on swallowing function. Individuals with a history of oropharyngeal and laryngeal cancer (n = 10) were also excluded because of dysphagia secondary to surgery and radiation therapy. Finally, 1,988 participants were available for the analysis (age range at baseline 65–89 years, median 71.0, interquartile range 6.0) (Figure 1).

Assessment of Swallowing Function

Swallowing function was evaluated with and without dentures in participants who wore and did not wear dentures during a meal, respectively.

By referring to the main clinical symptoms according to which dysphagia is suspected (20–22), four questionnaire items were used: Do you drop food from your mouth during a meal? Do you feel that food remains in your mouth? Do you choke during a meal? Do you cough during and after a meal?

The 30-mL water swallow test (23), which was developed to screen for dysphagia in individuals with cerebrovascular disease, was used to evaluate aspiration. Two trained dentists and four dental hygienists with extensive experience in evaluating the results of the water swallow test administered the test at the baseline and follow-up examinations. The participants were instructed to drink 30 mL of room-temperature

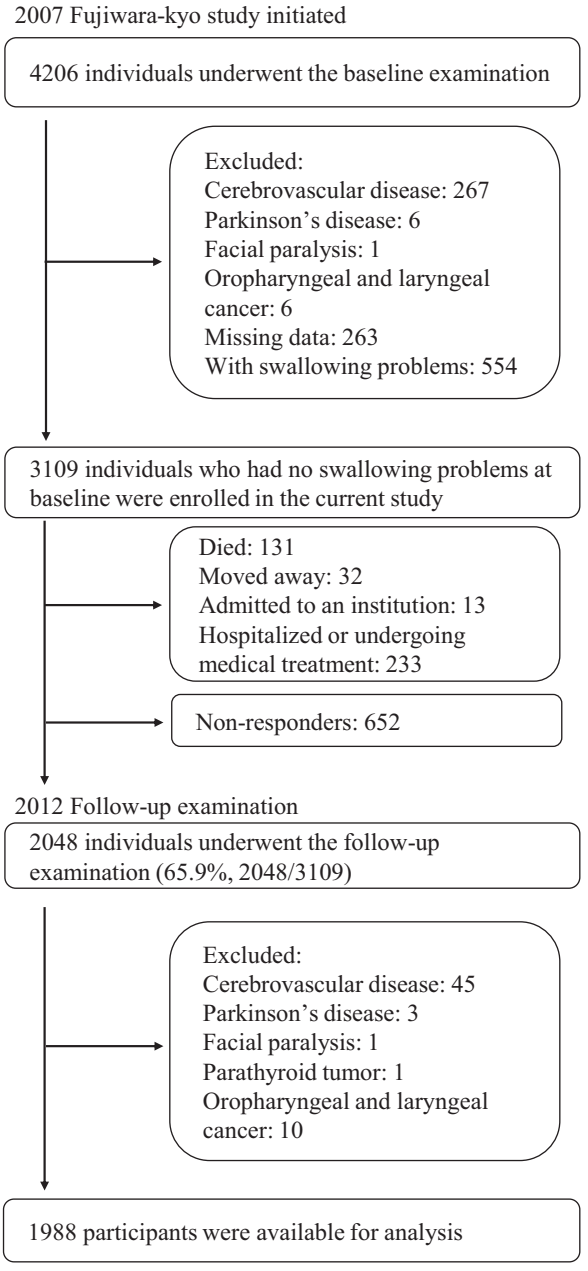

Figure 1. Selection of subjects.

water from a cup without interruption in a seated position, and the time taken to drink the water and the presence or absence of coughing were observed. The examiners (a combination of a dentist and a dental hygienist or a combination of two dentists) discussed their observations to arrive at a consensus. If it was suspected that some water was left in the mouth because a participant sipped the water, the examination was repeated. The participants were classified as normal when they drank the water in 5 seconds or less without interruption or coughing, and abnormal when they drank the water with interruptions or with coughing or it took longer than 5 seconds. When compared with videofluoroscopic examination of swallowing as the standard criterion, with a cutoff point of 5 seconds, the sensitivity and specificity of the water swallow test are 90% and 56%, respectively (23).

When the participants answered yes to any of the four questionnaire items or were judged to be abnormal according to the water swallow test, they were diagnosed with a swallowing problem (12). In our test–retest analysis on the presence or absence of swallowing problems 4 weeks later ($n = 44$), the kappa coefficient was .41 ($p = .004$).

Dental Examination

Number of Remaining Teeth

Dental examinations were carried out at the baseline and follow-up surveys by two dentists calibrated as to the techniques using the single observer method, with both the dentist and the participant in a sitting position under artificial lighting. The number of teeth was recorded for each participant. The remaining teeth were defined as healthy, carious, or treated (including crowned, inlay, and abutment teeth for bridge work), inclusive of completely erupted third molars. Root tips and very loose teeth that were indicated for extraction were not included as remaining teeth.

Maximum Bite Force

Maximum bite force by all dentition was measured using the Dental Prescale System (FPD-707; Fuji Film Co., Tokyo, Japan) (24). The participant bit a pressure-sensitive sheet (50H; Fuji Film Co.) as hard as possible in the intercuspal position for 3 seconds. The pressure-sensitive sheet showed occlusal contact area and different densities of color depending on the level of the pressure applied. The maximum bite force was determined by the area and density data with a color image scanner contained in the FPD-707. This measurement was taken with and without dentures in participants who wore and did not wear dentures during a meal, respectively.

Occlusal Support and Oral Dryness

Intermaxillary support, which includes artificial teeth in bridges and dentures, was evaluated according to the Eichner classification (25), in which the premolars and molars are counted as one region for a total of four supporting zones. Individuals classified as rank A have four occlusal contacts in the posterior region. Rank B or C refers to zero to three occlusal contacts in the posterior region. The participants were also asked whether they had subjective oral dryness.

Measurements of Potential Confounding Factors

We considered chronic diseases, lower body mass index, and lower physical function, which are observed frequently in elderly people, as potential confounding factors.

Public health nurses interviewed each participant to record any history of disease and current medication. Blood pressure was determined twice using an automatic blood-pressure manometer (ES-P2100; TERUMO Co., Tokyo, Japan). An average of two measurements was used in the analyses. Blood samples were collected from an antecubital vein after an overnight fast. Hemoglobin A1c values were converted to National Glycohemoglobin Standardization Program values according to the Japan Diabetes Society guidelines (26). Cancer and myocardial infarction were determined by medical history and current medication. Diabetes mellitus was defined by medical history, current antidiabetic medication, and/or by one of the following biochemical test results according to the guidelines of the American Diabetes Association (27) and the Japan Diabetes Society (28): fasting plasma glucose level ≥126 mg/dL or hemoglobin A1c level ≥6.5%. Hypertension was defined according to the Japanese Society of Hypertension criteria (29) as follows: medical history, current use of antihypertensive medicine, and/or systolic/diastolic blood pressure 140/90 mmHg or greater.

Height and body weight were measured with a body fat scale (TANITA Co. Tokyo, Japan) with the participant wearing an examination gown. Body mass index was calculated as weight (kg) divided by height squared (m^2).

In the 10-m walking test, the participants were instructed to walk in a straight line as quickly as possible along a 14-m pathway. Modulation-type optical input units (TAKEI Co., Niigata, Japan) were placed at the 2- and 12-m points, and the time taken by the participant to walk 10 m was measured. Grip strength of the dominant hand was measured by using a Smedley type digital dynamometer (TAKEI Co.) in a sitting position with the upper extremities in a natural downward position.

Statistical Analysis

Baseline characteristics were compared between subjects available for the analysis and subjects excluded from the analysis using the chi-square or Mann–Whitney test. The participants were classified into quartile groups according to the number of remaining teeth at the baseline survey: 0–12, 13–22, 23–26, and 27–32 teeth. Differences in the characteristics of the four tooth groups at baseline were analyzed using the chi-square or Kruskal–Wallis test. Trend tests were performed using the Mantel-extension method or Jonckheere test. Multivariate-adjusted odds ratios and 95% confidence intervals (CIs) were determined by using logistic regression analysis (by the forced entry method). The development of swallowing problems at follow-up was used as a dependent variable. The category of number of remaining teeth at baseline was used as independent variable. To investigate the effect of fewer teeth on swallowing problems, the effects of gender, age, Eichner classification A, presence of oral dryness, positive disease history (cancer, myocardial infarction, diabetes mellitus, and hypertension), body mass index, 10-m walking test, and grip strength were controlled as potential confounding factors. The decrease in the number of teeth (baseline number minus follow-up number) was also used as an independent variable in an additional logistic analysis. The number of teeth at baseline and a decrease in the number of teeth during the survey were added separately to each logistic model.

Statistical analysis was performed using SPSS version 17.0. Two-tailed p values were calculated in all of the analyses. The alpha level of significance was set at .05.

Results

Comparison of Baseline Characteristics Between the 1,988 Subjects Available for the Analysis and the 1,121 Subjects Excluded From the Analysis

At baseline, the excluded subjects were significantly older, had significantly fewer remaining teeth, had a significantly higher frequency

of edentulism, and had a significantly higher frequency of subjective oral dryness. The results of the 10-m walking test and grip strength test were significantly poorer in the excluded subjects (Table 1).

Relationship Between Tooth Loss and Swallowing Problems

Table 2 shows the characteristics of the 1,988 participants according to the number of remaining teeth at baseline. As the number of teeth was reduced, the maximum bite force was significantly reduced. Significant associations were found between having fewer teeth and older age, longer time required to complete the 10-m walking test, lower grip strength, smaller frequency of men, and greater prevalence of diabetes mellitus and hypertension.

The 5-year cumulative incidence of swallowing problems was 15.7% (312/1,988). It was 16.4% in men (n = 1,038, median age 71.0 years, interquartile range 7.0) and 14.9% in women (n = 950, median age 71.0 years, interquartile range 6.0) (p = .39) (Supplementary Appendix 1). Figure 2 illustrates the cumulative incidence of swallowing problems on the basis of the number of remaining teeth at baseline (27–32, 23–26, 13–22, and 0–12 teeth); the cumulative incidence was significantly greater with fewer teeth: 7.6%/12.0%/16.8%/18.2% in participants aged 65–74 years (p for trend < .001) and 14.9%/15.2%/28.4%/29.1% in those aged 75–89 years (p for trend = .002), respectively. Similar results were also found in the analysis separated by gender.

Table 3 shows the multivariate-adjusted odds ratios for the development of swallowing problems. Maximum bite force was not

Table 1. Comparison of the Baseline Characteristics Between the Subjects Available for the Analysis and Those Excluded From the Analysis

Variables	Subjects Available for the Analysis (n = 1,988)	Subjects Excluded From the Analysis (n =1,121)	p Value*
Men, %	1,038 (52.2)	482 (43.0)	<.001
Age, y	71.0 (6.0)	73.0 (8.0)	<.001
Oral health			
Number of remaining teeth	23.0 (14.0)	20.0 (17.0)	<.001
Edentulism, %	146 (7.3)	125 (11.2)	<.001
Maximum bite force, *N*	348.0 (423.2)	265.6 (366.4)	<.001
Eichner classification "A," %	1,729 (87.0)	967 (86.3)	.58
Complaints of oral dryness, %	17 (0.9)	20 (1.8)	.03
Positive history of disease			
Cancer (excluding oropharyngeal cancer), %	177 (8.9)	102 (9.1)	.85
Myocardial infarction, %	42 (2.1)	29 (2.6)	.45
Diabetes mellitus, %	268 (13.5)	163 (14.5)	.42
Hypertension, %	1,381 (69.5)	803 (71.6)	.22
Body mass index, kg/m^2	22.9 (3.6)	22.9 (4.0)	.19
10-m walking test, s	5.2 (1.2)	5.7 (1.4)	<.001
Grip strength, kg	29.3 (13.5)	25.8 (11.4)	<.001

Notes: Data are given as number (%) or median (interquartile range).
*Differences between both groups were analyzed using the chi-square or Mann–Whitney test.

Table 2. Clinical Characteristics of 1,988 Participants by the Number of Remaining Teeth at Baseline

Variables	Quartiles of the Number of Remaining Teeth				p Value*	p Value†
	Q4 (27–32) n = 513	Q3 (23–26) n = 515	Q2 (13–22) n = 477	Q1 (0–12) n = 483		
Men, %	296 (57.7)	268 (52.0)	236 (49.5)	238 (49.3)	.03	.005
Age, y	69.0 (5.0)	70.0 (6.0)	71.0 (6.0)	73.0 (7.0)	<.001	<.001
Oral health						
Number of remaining teeth	28.0 (2.0)	25.0 (2.0)	19.0 (5.0)	5.0 (9.0)	<.001	<.001
Maximum bite force, *N*	603.9 (391.9)	474.0 (358.2)	294.6 (243.3)	129.1 (156.6)	<.001	<.001
Eichner classification "A," %	509 (99.2)	427 (82.9)	334 (70.0)	459 (95.0)	<.001	<.001
Complaints of oral dryness, %	3 (0.6)	5 (1.0)	2 (0.4)	7 (1.4)	.31	.27
Positive history of disease						
Cancer (excluding oropharyngeal cancer), %	42 (8.2)	42 (8.2)	46 (9.6)	47 (9.7)	.70	.29
Myocardial infarction, %	12 (2.3)	11 (2.1)	6 (1.3)	13 (2.7)	.46	.96
Diabetes mellitus, %	46 (9.0)	75 (14.6)	71 (14.9)	76 (15.7)	.006	.002
Hypertension, %	330 (64.3)	366 (71.1)	341 (71.5)	344 (71.2)	.04	.02
Body mass index, kg/m^2	22.9 (3.2)	22.9 (3.4)	22.9 (3.8)	22.7 (4.2)	.91	.75
10-m walking test, s	5.0 (1.2)	5.2 (1.2)	5.3 (1.2)	5.5 (1.2)	<.001	<.001
Grip strength, kg	31.3 (14.5)	29.6 (13.5)	28.9 (12.5)	27.9 (13.4)	<.001	<.001

Note: Data are given as number (%) or median (interquartile range).
*Differences between the four groups were analyzed using the chi-square or Kruskal–Wallis test.
†A trend test was performed using the Mantel-extension method or Jonckheere test.

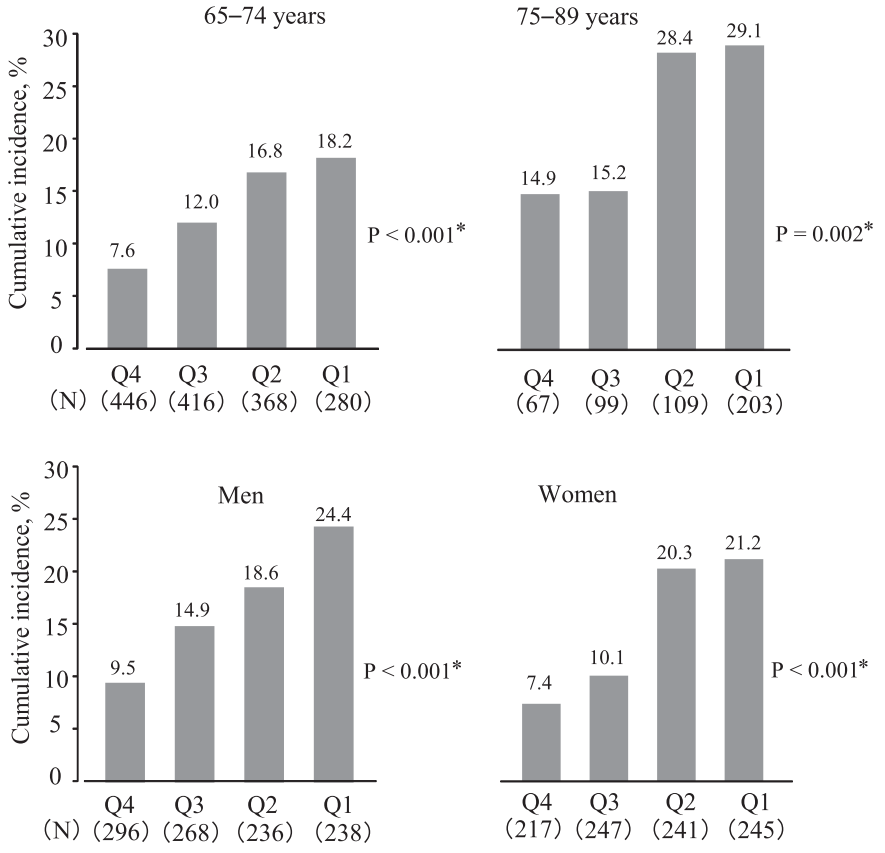

Figure 2. Five-year cumulative incidence of swallowing problems according the number of remaining teeth at baseline. Q1–Q4 show the number of remaining teeth (Q1: 0–12; Q2: 13–22; Q3: 23–26, and Q4: 27–32). *A trend test was performed to detect the greater cumulative incidence of swallowing problems with fewer remaining teeth using the Mantel-extension method.

Table 3. Multivariate-Adjusted Odd Ratios for the Development of Swallowing Problems in 1,988 Participants During the 5-Year Follow-up Period

Variables	Adjusted odds ratio (95% confidence interval)	*p* Value
Men	1.18 (0.88–1.57)	.28
Age, per 1 year increase	1.04 (1.01–1.07)	.004
Number of remaining teeth		
27–32	1	
23–26	1.46 (0.97–2.21)	.07
13–22	2.42 (1.61–3.63)	<.001
0–12	2.49 (1.68–3.69)	<.001
Eichner classification "A"	1.13 (0.76–1.66)	.55
Complaints of oral dryness	0.74 (0.20–2.79)	.66
Positive history of disease		
Cancer	0.99 (0.64–1.51)	.94
Myocardial infarction	1.97 (0.95–4.07)	.07
Diabetes mellitus	0.94 (0.66–1.33)	.72
Hypertension	0.97 (0.73–1.29)	.84
Body mass index, per 1 kg/m^2 increase	0.99 (0.95–1.04)	.90
10-m walking test, per 1 s increase	1.21 (1.08–1.36)	.001
Grip strength, per 1 kg increase	1.01 (0.99–1.01)	.30

Notes: Adjusted for sex, age, number of remaining teeth, Eichner classification, oral dryness, positive disease history, body mass index, 10-m walking test, and grip strength.

used as an independent variable because of a significant correlation with the number of remaining teeth (Spearman's rank correlation coefficient .65). Hosmer–Lemeshow analysis provided no evidence for the lack of fit (p = .99). After adjustment for confounding factors in the full model, the odds ratios of 13–22 and 0–12 teeth were 2.42 (95% CI, 1.61–3.63) and 2.49 (95% CI, 1.68–3.69), respectively, compared to participants with 27–32 teeth, demonstrating a significant relationship (p for trend < .001). In an additional logistic model, after adjustment for confounding factors, the odds ratio of per 1 tooth decreased over 5 years was 1.08 (95% CI, 1.02–1.13, p = .008).

Discussion

As far as we know, this is the first prospective cohort study on the relationship between the number of teeth and swallowing problems in elderly people living independently. After adjustment for the effects of age, disease history, and physical function, logistic regression analysis indicated that significant relationships remained between swallowing problems and a smaller number of remaining teeth, and between swallowing problems and decrease in the number of teeth during the survey.

In the test–retest analysis on swallowing function, moderate repeatability was observed (the kappa coefficient was .41). The validity of this screening test was not verified using videofluoroscopy. However, the prevalence of swallowing problems (15.1%) at

the baseline examination in this study (12) was similar to the percentage (13.8%) of participants with swallowing problems identified from among 1,313 community-dwelling elderly individuals in Akita prefecture, Japan, using a different dysphagia screening questionnaire (21). Therefore, it is likely that this survey identified individuals who experienced impaired swallowing.

Mastication serves to form a well-lubricated and cohesive food bolus, through the insalivation and comminution of food (30). The total number of chews and duration of mastication to adjust food particles to the proper size increased in post-stroke patients and complete denture wearers because of insufficient masticatory ability (31,32). Chewing for a longer time can reduce bolus viscosity (31). As bolus viscosity decreases, the location of the leading edge tends to be significantly deeper in the pharynx (33), increasing the chance of aspiration. Individuals with fewer teeth have lower masticatory ability. They may have difficulty in forming a bolus with a viscosity and particle size suitable for swallowing without a delay in the initiation of swallowing. Swallowing problems may be more likely to develop in elderly individuals with fewer teeth because of reduced bolus viscosity.

Age-related changes of swallowing in a healthy older population are referred to as presbyphagia (9) and distinguished from dysphagia in post-stroke patients. Independent elderly individuals with fewer remaining teeth do not generally undergo swallowing rehabilitation; however, once their physical condition worsens, they might become susceptible to pneumonia due to silent aspiration. It is important to keep one's teeth while maintaining good oral hygiene.

Logistic regression analysis showed no significant relationship between the Eichner classification and swallowing problems (Table 3). Laryngeal penetration is significantly greater in frequency in edentulous older people not wearing their dentures than in dentulous older people (34). Without dentures, bolus transit time is increased in the oral cavity, valleculae, and hypopharynx because of poor food manipulation and poor bolus formation than with dentures (35). The prolonged residence of the bolus in the hypopharynx may increase the risk of aspiration. Therefore, jaw stabilization by occlusion with posterior teeth or dental prosthetics has an important role in swallowing function.

Four limitations of the present study merit consideration. The primary limitation is that the proportion of nonresponse participants was high. The proportion of edentulous individuals and individuals with a smaller number of remaining teeth was greater in the subjects excluded from the analysis (Table 1). We speculate that a high-risk population for the development of swallowing problems was excluded from this study. It is unclear whether the association between tooth loss and swallowing problems was overestimated or underestimated. Second, we did not perform a solid food test. A water bolus may be swallowed without being masticated. We might have misclassified individuals who sometimes coughed when they swallowed solid food as persons with normal function. Third, the positions of the tooth defects were not investigated, which may affect maximum bite force and swallowing function. Fourth, no data were available for pharyngeal manometric peak pressure and tongue strength, which have been shown to be significantly reduced in aspirators compared with non-aspirators (36,37). The lack of the evaluation of associations between these data and swallowing function might have resulted in an overestimation of the association between mastication and swallowing problems.

Conclusions

Swallowing problems due to aging are more likely to develop in individuals with fewer teeth. Preventive measures against tooth loss in adulthood can reduce the risk of swallowing dysfunction at an older age. Subjects who have already experienced marked tooth loss should use dentures to maintain jaw stabilization.

Supplementary Material

Supplementary material can be found at: http://biomedgerontology.oxfordjournals.org/

Funding

This work was supported by a Grant-in-Aid for Young Scientists (No. 22790566; 2010–2013) from the Japanese Ministry of Education, Culture, Sports, Science, and Technology, a research grant J110400001 from Nara Medical University (2007–2012), and a research grant from the Taiyo Life Welfare Foundation (2011).

References

1. Martino R, Foley N, Bhogal S, Diamant N, Speechley M, Teasell R. Dysphagia after stroke: incidence, diagnosis, and pulmonary complications. *Stroke*. 2005;36:2756–2763. doi:10.1161/01.STR.0000190056.76543.eb
2. Miller N, Allcock L, Hildreth AJ, Jones D, Noble E, Burn DJ. Swallowing problems in Parkinson disease: frequency and clinical correlates. *J Neurol Neurosurg Psychiatry*. 2009;80:1047–1049. doi:10.1136/jnnp.2008.157701
3. Sonies BC. Oropharyngeal dysphagia in the elderly. *Clin Geriatr Med*. 1992;8:569–577.
4. Sheth N, Diner WC. Swallowing problems in the elderly. *Dysphagia*. 1988;2:209–215.
5. Crary MA, Groher ME. *Introduction to Adult Swallowing Disorders*. St. Louis, MO: Butterworth-Heinemann; 2003.
6. Yoshikawa M, Yoshida M, Nagasaki T, et al. Aspects of swallowing in healthy dentate elderly persons older than 80 years. *J Gerontol A Biol Sci Med Sci*. 2005;60:506–509. doi:10.1093/gerona/60.4.506
7. Feng X, Todd T, Lintzenich CR, et al. Aging-related geniohyoid muscle atrophy is related to aspiration status in healthy older adults. *J Gerontol A Biol Sci Med Sci*. 2013;68:853–860. doi: 10.1093/gerona/gls225
8. Nicosia MA, Hind JA, Roecker EB, et al. Age effects on the temporal evolution of isometric and swallowing pressure. *J Gerontol Med Sci*. 2000;55A:M634–M640. doi:10.1093/gerona/55.11.M634
9. Leslie P, Drinnan MJ, Ford GA, Wilson JA. Swallow respiratory patterns and aging: presbyphagia or dysphagia? *J Gerontol A Biol Sci Med Sci*. 2005;60:391–395. doi:10.1093/gerona/60.3.391
10. Butler SG, Stuart A, Kemp S. Flexible endoscopic evaluation of swallowing in healthy young and older adults. *Ann Otol Rhinol Laryngol*. 2009;118:99–106.
11. Almirall J, Rofes L, Serra-Prat M, et al. Oropharyngeal dysphagia is a risk factor for community-acquired pneumonia in the elderly. *Eur Respir J*. 2013;41:923–928. doi:10.1183/09031936.00019012
12. Okamoto N, Tomioka K, Saeki K, et al. Relationship between swallowing problems and tooth loss in community-dwelling independent elderly adults: the Fujiwara-kyo study. *J Am Geriatr Soc*. 2012;60:849–853. doi:10.1111/j.1532-5415.2012.03935.x
13. Prinz JF, Lucas PW. Swallow thresholds in human mastication. *Arch Oral Biol*. 1995;40:401–403.
14. Okamoto N, Morikawa M, Okamoto K, et al. Relationship of tooth loss to mild memory impairment and cognitive impairment: findings from the Fujiwara-kyo study. *Behav Brain Funct*. 2010;6:77. doi:10.1186/1744-9081-6-77
15. Okamoto N, Morikawa M, Okamoto K, et al. Tooth loss is associated with mild memory impairment in the elderly: the Fujiwara-kyo study. *Brain Res*. 2010;1349:68–75. doi:10.1016/j.brainres.2010.06.054
16. Morikawa M, Okamoto N, Kiuchi K, et al. Association between depressive symptoms and metabolic syndrome in Japanese community-dwelling older people: a cross-sectional analysis from the baseline results of the Fujiwara-kyo prospective cohort study. *Int J Geriatr Psychiatry*. 2013;28:1251–1259. doi:10.1002/gps.3950

17. Tomioka K, Iwamoto J, Saeki K, Okamoto N. Reliability and validity of the International Physical Activity Questionnaire (IPAQ) in elderly adults: the Fujiwara-kyo study. *J Epidemiol*. 2011;21:459–465. doi:10.2188/jea.JE20110003
18. Hirayama A, Torimoto K, Mastusita C, et al. Evaluation of factors influencing the natural history of nocturia in elderly subjects: results of the Fujiwara-kyo Study. *J Urol*. 2013;189:980–986. doi:10.1016/j.juro.2012.09.118
19. Fujita Y, Iki M, Tamaki J, et al. Renal function and bone mineral density in community-dwelling elderly Japanese men: the Fujiwara-kyo Osteoporosis Risk in Men (FORMEN) Study. *Bone*. 2013;56:61–66. doi:10.1016/j.bone.2013.05.004
20. Miura H, Kariyasu M, Yamasaki K, Arai Y. Evaluation of chewing and swallowing disorders among frail community-dwelling elderly individuals. *J Oral Rehabil*. 2007;34:422–427. doi:10.1111/j.1365-2842.2007.01741.x
21. Kawashima K, Motohashi Y, Fujishima I. Prevalence of dysphagia among community-dwelling elderly individuals as estimated using a questionnaire for dysphagia screening. *Dysphagia*. 2004;19:266–271. doi:10.1007/s00455-004-0013-6
22. Fujishima I, Takahashi H, Setsu K, Inao A. Screening test for dysphagia [in Japanese]. *J Clin Rehabil*. 2002;11:790–796.
23. Kubota T, Mishima H, Hanada M, Nanba I, Kozima Y. Dysphagia paralytica in cerebrovascular disease: screening test and its clinical application [in Japanese]. *Sogo Rehabil*. 1982;10:271–276.
24. Suzuki T, Kumagai H, Watanabe T, Uchida T, Nagao M. Evaluation of complete denture occlusal contacts using pressure-sensitive sheets. *Int J Prosthodont*. 1997;10:386–391.
25. Swoboda J, Kiyak HA, Persson RE, et al. Predictors of oral health quality of life in older adults. *Spec Care Dentist*. 2006;26:137–144.
26. Kashiwagi A, Kasuga M, Araki E, et al. International clinical harmonization of glycated hemoglobin in Japan: from Japan Diabetes Society to National Glycohemoglobin Standardization Program values. *J Diabetes Investig*. 2012;3:39–40. doi:10.1111/j.2040-1124.2012.00207.x
27. American Diabetes Association. Diagnosis and classification of diabetes mellitus. *Diabetes Care*. 2014;37:S81–S90. doi:10.2337/dc14-S081
28. Seino Y, Nanjo K, Tajima N, et al. Report of the committee on the classification and diagnostic criteria of diabetes mellitus (revision for international harmonization of HbA1c in Japan) [in Japanese]. *J Jpn Diabetes Soc*. 2012;55:485–504. doi:10.11213/tonyobyo.55.485
29. Ogihara T, Kikuchi K, Matsuoka H, et al. The Japanese Society of Hypertension Guidelines for the Management of Hypertension (JSH2009). *Hypertens Res*. 2009;32:3–107. doi:10.1038/hr.2008.18
30. Woda A, Mishellany A, Peyron MA. The regulation of masticatory function and food bolus formation. *J Oral Rehabil*. 2006;33:840–849. doi:10.1111/j.1365-2842.2006.01626.x
31. Kim IS, Han TR. Influence of mastication and salivation on swallowing in stroke patients. *Arch Phys Med Rehabil*. 2005;86:1986–1990. doi:10.1016/j.apmr.2005.05.004
32. Veyrune JL, Lassauzay C, Nicolas E, Peyron MA, Woda A. Mastication of model products in complete denture wearers. *Arch Oral Biol*. 2007;52:1180–1185. doi:10.1016/j.archoralbio.2007.04.016
33. Matsuo K, Kawase S, Wakimoto N, Iwatani K, Masuda Y, Ogasawara T. Effect of viscosity on food transport and swallow initiation during eating of two-phase food in normal young adults: a pilot study. *Dysphagia*. 2013;28:63–68. doi:10.1007/s00455-012-9413-1
34. Yoshikawa M, Yoshida M, Nagasaki T, Tanimoto K, Tsuga K, Akagawa Y. Influence of aging and denture use on liquid swallowing in healthy dentulous and edentulous older people. *J Am Geriatr Soc*. 2006;54:444–449. doi:10.1111/j.1532-5415.2005.00619.x
35. Yamamoto H, Furuya J, Tamada Y, Kondo H. Impacts of wearing complete dentures on bolus transport during feeding in elderly edentulous. *J Oral Rehabil*. 2013;40:923–931. doi:10.1111/joor.12107
36. Butler SG, Stuart A, Wilhelm E, Rees C, Williamson J, Kritchevsky S. The effects of aspiration status, liquid type, and bolus volume on pharyngeal peak pressure in healthy older adults. *Dysphagia*. 2011;26:225–231. doi:10.1007/s00455-010-9290-4
37. Butler SG, Stuart A, Leng X, et al. The relationship of aspiration status with tongue and handgrip strength in healthy older adults. *J Gerontol A Biol Sci Med Sci*. 2011;66:452–458. doi:10.1093/gerona/glq234