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# Evaluation of chewing ability and its relationship with activities of daily living, depression, cognitive status and food intake in the community-dwelling elderly

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**Aim:** The aim of this study was to assess chewing ability using color-changeable chewing gum and to show the association between chewing ability and geriatric functions, as well as dietary status in the community-dwelling elderly.

**Methods:** The study population consisted of 269 community-dwelling elderly aged ≥75 living in Tosa, Japan. Assessment of chewing ability was carried out by a dentist using color-changeable chewing gum. Activities of daily living (ADL), depression and subjective quality of life (QOL) were assessed by questionnaire. Cognitive status was assessed by; Mini-Mental State Examination (MMSE), Hasegawa Dementia Scale-Revised (HDS-R) and Frontal Assessment Battery (FAB) during the check-up. Food diversity was assessed using the 11-item Food Diversity Score Kyoto (FDSK-11).

**Results:** Number of teeth was significantly related to chewing ability ($P < 0.001$). The participants with low chewing ability had significantly lower ADL scores in the items of self-maintenance ($P = 0.029$) and intellectual activity ($P = 0.021$). There was a significant association between low chewing ability and depression ($P < 0.001$). Lower cognitive functions were significantly related to low chewing ability; MMSE ($P = 0.022$), HDSR ($P = 0.017$) and FAB ($P = 0.002$). The participants with low chewing ability had lower food variety ($P < 0.001$), and less frequent intake of beans, vegetables, seaweed and nuts, than the participants with high chewing ability.

**Conclusion:** Low chewing ability evaluated by color-changeable gum was associated with lower ADL, lower cognitive functioning, depression and food insufficiency in the community-dwelling elderly. More attention should be paid to assessing chewing ability of elderly persons in community settings. **Geriatr Gerontol Int 2013; 13: 718–725.**

**Keywords:** activities of daily living, chewing ability, cognitive function, depression, dietary intake.

## Introduction

Oral health is a very important factor in the well-being of the elderly population. Earlier research by the authors of the current study identified a relationship between greater self-rated chewing difficulty and lower ability to carry out activities of daily living (ADL), lower quantitative subjective quality of life (QOL), and higher risk of depression among the community-dwelling elderly.[1] In addition to self-rated chewing difficulty, objective dental assessments of the elderly in community settings are required to gain further understanding of actual oral health and its relationship with other aspects of health status through comprehensive geriatric assessment (CGA) among the elderly.[2] However, simultaneously using both means of assessment in a community setting is difficult, as CGA is a time-consuming process that requires completion of a variety of items.

In recent years, a relatively easy method for the evaluation of masticatory performance by using color-changeable chewing gum has been introduced,[3] and its

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validity and reliability have been reported.[4] According to the latest report, use of this method has allowed researchers to carry out surveys of the elderly population in clinical settings to evaluate the associations between masticatory performance, and both anthropometric measurements and nutritional status.[5] Using this method to assess chewing ability in community settings might also be a relatively easy means of assessing these relationships along with CGA. The goal of the present study was to examine the relationship between chewing ability, and both comprehensive geriatric functions and dietary status in the community-dwelling elderly population by using color-changeable chewing gum.

## Methods

### *Study design*

The present study was a cross-sectional study.

### *Ethical clearance*

This study was approved by the Ethical Committee of the Faculty of Medicine, Kyoto University, Kyoto, Japan (E-514).

### *Study population*

The present study examined 269 community-dwelling elderly individuals (88 men and 181 women) aged 75 years and older (mean ± standard deviation = 80.6 ± 4.7 years) currently residing in the town of Tosa, Kochi Prefecture, Japan, who had agreed to undergo CGA and had completed the applicable portions of the assessment in 2010. As the total population of the community-dwelling elderly aged 75 years and older in Tosa is 960 (excluding those being cared for at a hospital or nursing home), and 333 had agreed to undergo CGA in 2010, the study population represented 28.0% of the eligible population. Tosa is a rural farming town in a mountainous area that is known as one of the "super-aged" towns in Japan, having an aging rate of 41.3%.

### *Oral assessment*

During the oral assessment, assessment of chewing ability was carried out by one dentist using Masticatory Performance Evaluating Gum (XYLITOL, 70 mm × 20 mm × 1 mm, 3.0 g; Lotte, Saitama, Japan), which changes color depending on chewing performance. The participants were asked to chew the gum for 1 min as they usually chew foods. Immediately after they had chewed the gum for 2 min, the dentist checked the color of the chewed gum using a color chart with five color gradations 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).

Using a questionnaire, the participants were asked to respond "yes" or "no" to the question "In the past 6 months, have you had difficulty chewing when you eat hard foods?" to assess the subjective sense of chewing difficulty.[1] The dentist also determined the number of teeth and the use of dentures for each participant during the oral assessment.

### *Geriatric functioning*

Using a questionnaire, the ability to carry out ADL, presence of depressive symptoms and quantitative subjective QOL were determined to assess geriatric functioning. To assess the basic ability to carry out ADL, the participants were assigned a score ranging from 0 (completely dependent) to 3 (completely independent), reflecting their ability to carry out seven tasks: (i) walking; (ii) ascending and descending stairs; (iii) feeding themselves; (iv) dressing; (v) using the toilet; (vi) bathing; and (vii) grooming. The individual ADL scores were then summed to obtain a basic ADL score ranging from 0 to 21, with lower scores indicating greater disability.[6,7] For advanced ADL, the participants were assessed using the Tokyo Metropolitan Institute of Gerontology Index of Competence (TMIG-IC) scale,[8] a rated scale (0–13) that evaluates instrumental self-maintenance (0–5), intellectual activity (0–4) and social roles (0–4). The presence of depressive symptoms was screened using the Japanese version of the 15-item Geriatric Depression Scale (GDS-15).[9,10] Quantitative QOL was assessed using a 100-mm visual analog scale (lowest QOL on the left and highest on the right) that assessed five variables: (i) subjective sense of health; (ii) relationship with family; (iii) relationship with friends; (iv) financial satisfaction; and (v) subjective happiness.[11]

### *Cognitive status*

Cognitive status was assessed by clinical psychotherapists and well-trained staff by using the Mini-Mental State Examination (MMSE),[12] Hasegawa Dementia Scale-Revised (HDS-R)[13] and Frontal Assessment Battery (FAB)[14] during the CGA.

### *Dietary status*

Food diversity was assessed as a measure of dietary quality using the 11-item Food Diversity Score Kyoto (FDSK-11),[15] which evaluates frequency of consumption of 11 main food groups (grain, meat, fish and shellfish, eggs, milk, beans and soybean products, potatoes, 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

**Table 1** Baseline characteristics of the study participants

| Chewing ability | *n* | Age, mean ± SD | Sex (male/female) | Use of dentures (%) |
|---|---|---|---|---|
| 1 (Very poor) | 6 | 83.0 ± 6.1 | 1/5 | 66.7 |
| 2 (Poor) | 21 | 81.1 ± 3.2 | 5/16 | 81.0 |
| 3 (Moderate) | 78 | 81.7 ± 5.1 | 19/59 | 94.9 |
| 4 (Good) | 148 | 80.3 ± 4.4 | 58/90 | 62.8 |
| 5 (Very good) | 16 | 78.1 ± 4.0 | 5/11 | 31.3 |
| Total | 269 | 80.8 ± 4.6 | 88/181 | 71.7 |

SD, standard deviation. Use of dentures: includes one or more partial dentures.

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).

### *Lifestyle characteristics*

To obtain data regarding their lifestyle characteristics, the participants completed a questionnaire containing items regarding their education, economic status, living/eating arrangements, employment, physical activity level, alcohol consumption and smoking habits.

### *Prevalence of lifestyle-related diseases*

Prevalence of lifestyle-related diseases was determined by blood chemical testing and analysis of medical records. The criteria for diagnosis of hypertension were systolic blood pressure of 140 mmHg or higher and/or diastolic pressure of 90 mmHg or higher. The criteria for hypercholesterolemia were a total cholesterol level of ≥220 mg/dL and/or a low-density lipoprotein (LDL) cholesterol level of ≥140 mg/dL. The criteria for diabetes mellitus was a casual blood glucose level of ≥200 mg/dL and/or an glycated hemoglobin level of ≥6.5. The criterion for impaired glucose tolerance was a casual blood glucose level of ≥140 mg/dL.

### *Statistical analysis*

Statistical analysis was carried out using SPSS version 19.0 for Windows (SPSS, Chicago, IL, USA). The Student's *t*-test was used for continuous variables and the $\chi^2$-test for categorical variables. A *P*-value of <0.05 was considered an indication of statistical significance.

## Results

The number of participants, mean age, sex distribution and the percentage of the participants who were wearing dentures (including one or more partial dentures) among the five levels of chewing ability are shown in Table 1. Six participants with a mean age of 83.0 ± 6.1 years were found to have very poor chewing ability (a score of 1), whereas 16 with a mean age of 78.1 ± 4.0 years were found to have very good chewing ability (a score of 5).

For comparison, all the participants were assigned into one of two groups, either a group with a relatively low chewing ability; a score between 1 and 3 ($n = 105$), or a group with a relatively high chewing ability; a score of 4 or 5 ($n = 164$) (Table 2). The group with low chewing ability was found to have a higher mean age, a significantly greater subjective sense of chewing difficulty ($P = 0.005$) and significantly fewer teeth ($P < 0.001$) than the group with high chewing ability. Regarding the last variable, a very large difference in the mean number of teeth was identified among the participants according to ability to chew foods; participants with a chewing ability score of 1 had a mean of 0.4 teeth, whereas those with a score of 5 had a mean of 22.5 teeth (Fig. 1).

In terms of geriatric functioning, participants with low chewing ability obtained significantly lower scores on the TMIG-IC ($P = 0.047$), including scores for engaging in self-maintenance ($P = 0.029$) and intellectual activity ($P = 0.021$), than those with high chewing ability, even after adjustment for age. A significant association was found between low chewing ability and the presence of depressive symptoms as assessed by the GDS-15 ($P < 0.001$), as well as between low chewing ability and relatively lower cognitive functioning as assessed by the MMSE ($P = 0.022$), HDSR ($P = 0.017$) and FAB ($P = 0.002$), even after adjustment for age. No significant association was found between chewing ability and QOL.

A direct relationship was found between food diversity as assessed by FDSK-11 score and chewing ability score (Fig. 1). The results of Tukey's honestly significant differences post-hoc test showed a significant difference in the FDSK-11 scores between participants with chewing ability scores of 1 and 3 ($P = 0.01$), and between participants with scores of 2 and 5 ($P = 0.03$). As shown in Table 3, comparison of frequency of intake of 11 food items by FDSK-11 score showed that

**Table 2** Comparison of oral status, geriatric functions and cognitive status between elderly with low and high chewing ability

| | Chewing ability | | *P*-value |
|---|---|---|---|
| | Low (score 1–3; *n* = 105) | High (score 4, 5; *n* = 164) | |
| Age, years (mean ± SD) | 81.6 ± 4.9 | 80.1 ± 4.4 | 0.023 |
| Sex (male/female) | 25/80 | 63/101 | 0.053 |
| Body mass index (mean ± SD) | 22.6 ± 3.4 | 23.3 ± 3.2 | 0.087 |
| Oral status | | | |
| No. teeth | 3.7 ± 5.7 | 14.6 ± 10.1 | <0.001 |
| Subjective sense of chewing difficulty (%) | 52.6 | 33.7 | 0.005 |
| Geriatric functions | | | |
| ADL (mean ± SD) | | | |
| Basic ADL score (range 0–21) | 20.0 ± 1.0 | 20.3 ± 1.6 | 0.137† |
| TMIG-IC (range 0–13) | 10.8 ± 2.3 | 11.4 ± 1.9 | 0.047† |
| Self-maintenance (range 0–5) | 4.3 ± 0.9 | 4.7 ± 0.7 | 0.029† |
| Intellectual activity (range 0–4) | 3.0 ± 1.2 | 3.3 ± 0.9 | 0.021† |
| Social role (range 0–4) | 3.1 ± 1.0 | 3.3 ± 1.0 | 0.067† |
| Depression, mean ± SD (range 0–15) | | | |
| Geriatric Depression Scale | 5.4 ± 3.3 | 3.9 ± 3.5 | <0.001 |
| QOL, mean ± SD (range 0–100) | | | |
| Subjective sense of health | 56.5 ± 19.8 | 57.4 ± 19.4 | 0.681 |
| Relationship with family | 78.8 ± 18.2 | 82.2 ± 18.3 | 0.140 |
| Relationship with friends | 77.4 ± 17.9 | 76.5 ± 20.6 | 0.692 |
| Financial satisfaction | 55.0 ± 21.7 | 56.0 ± 23.1 | 0.883 |
| Subjective happiness | 60.5 ± 21.0 | 64.5 ± 21.3 | 0.093 |
| Cognitive status | | | |
| MMSE, mean ± SD (range 0–30) | 25.2 ± 3.8 | 26.2 ± 3.2 | 0.022† |
| HDSR, mean ± SD (range 0–30) | 25.3 ± 4.2 | 26.5 ± 3.5 | 0.017† |
| FAB, mean ± SD (range 0–18) | 11.0 ± 2.7 | 12.0 ± 2.6 | 0.002† |

*P*-values were calculated using the Student's *t*-test for continuous variables and the $\chi^2$-test for categorical variables. †After adjustment for age by ANCOVA. FAB, Frontal Assessment Battery; HDS-R, Hasegawa Dementia Scale-Revised; MMSE, Mini-Mental State Examination, SD, Standard Deviation; TMIG-IC, Tokyo Metropolitan Institute of Gerontology Index of Competence.

participants with lower chewing ability consumed a significantly lower variety of food items ($P < 0.001$), and were particularly less likely to consume fewer beans, vegetables, seaweed and nuts compared with participants with high chewing ability.

Regarding lifestyle-related factors, a significantly greater percentage of participants with high chewing ability were found to be employed or engaged in farming more than once a week ($P < 0.001$) and to engage in physical activity/exercise ($P = 0.032$) compared with those with low chewing ability (Table 4). In contrast, no significant associations were found between chewing ability and lifestyle-related diseases.

## Discussion

To the authors' knowledge, this was the first study to use color-changeable chewing gum to evaluate chewing ability among a sample of the community-dwelling elderly population to identify associations between chewing ability, and both geriatric functions and dietary status. The results show that elderly individuals with relatively low chewing ability tend to be older than those with relatively high chewing ability, and thus agree with many previous studies that found that chewing ability declines with age.[16,17] Furthermore, identification of the same relationship between low chewing ability and a smaller number of teeth and a greater subjective sense of chewing difficulty – as has been reported by previous studies – supports the reliability of these results, and thus, the utility of the study methodology. As the present study focused on the "older-elderly," defined as those aged 75 years and older, the results convey the important message that chewing ability is associated with age even among the "very old" elderly population, and thus highlight that maintaining oral health is important across the entire lifespan.

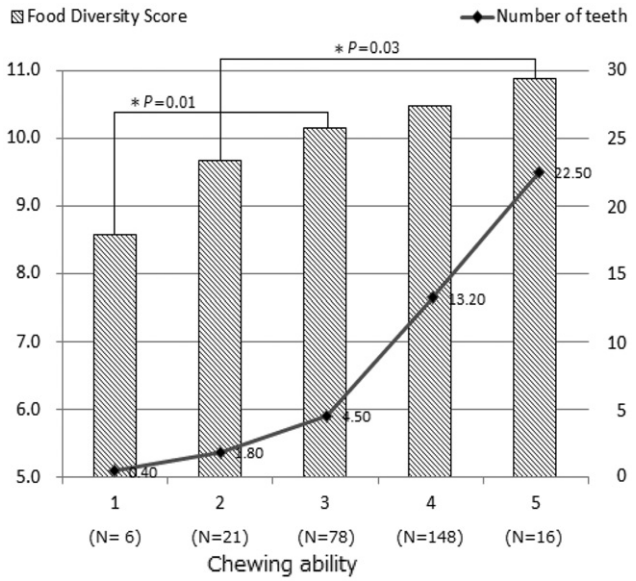


**Figure 1** Food diversity increased with chewing ability. *Statistically significant by Tukey's honestly significant differences post-hoc test.

The results also show an association between low chewing ability and less ability to carry out ADL, including less ability to carry out self-maintenance tasks and to engage in intellectual activity. This finding suggests that elderly persons who can continue to carry out ADL, such as cooking and using public transportation, are more motivated to maintain their oral health and face fewer barriers to engaging in preventive actions, such as brushing their teeth well or seeing their dentists. The elderly persons with higher ability to engage in intellectual activity are considered to be relatively more able to consume health-related information and to be more concerned with their oral health.

The identification of an association between depressive mood, as screened by the GDS-15, and low chewing ability agrees with the findings of a previous study by the authors of the present study.[1] However, the previous study assessed chewing ability by self-report measures, and as the subjective sense of chewing difficulty can be affected by mood, depressed participants might have answered negatively to questions on the basis of their mood rather than providing true data regarding their chewing ability. Using objective measures, the present study confirmed the existence of an association between chewing ability and depression. As more women than men were included in the present study, the effect of sex on depression, which has been found to be more prevalent in women,[10] was considered by adjusting for sex. After making this adjustment, a significant relationship was still observed between low chewing ability and depression ($P = 0.002$).

The results of the present study show that cognitive status as assessed by the MMSE, HDSR and FAB is related to chewing ability. They agree with the findings of several previous studies that identified relationships between cognitive status and indicators of oral health among the elderly, including a relationship between the number of teeth and dementia,[18] as well as between bite force, occlusal contact area, and self-rated mastication and cognitive functioning.[19] The present study supports and adds to the significance of previous research by identifying an association between chewing ability and cognitive functioning in the community-dwelling elderly.

The present study also identified important relationships between food intake and chewing ability. The results indicate a relationship between low chewing ability and a less varied diet, which is associated with lower health status[15] and even mortality[20] in elderly individuals. The results regarding frequency of food intake suggest that experiencing chewing difficulty might lead to avoidance of hard foods, such as beans, vegetables and nuts. As the present study was a cross-sectional study, the possibility of an opposite causal association should be considered, as less frequent intake of vegetables might lead to lower chewing ability. Indeed, one longitudinal study identified a negative correlation between vegetable intake and the risk of periodontal disease events.[21] Nevertheless, masticatory performance has been reported to relate with nutritional status as evaluated by bodyweight and mid-upper arm circumference,[5] which supports the findings of the present study and indicates that, because of its relationship with food insufficiency, low chewing ability might be an indicator of risk of malnutrition among the elderly in the community.

A higher proportion of participants with high chewing ability were found to be employed or to engage in farming, which suggests that elderly persons who can work might have higher physical ability, resulting in better oral health. Previous research has suggested that dental occlusion is associated with physical fitness.[22,23] The finding of a relationship between high chewing ability and greater physical activity can be also explained by this association.

Although the results of the present study showed no significant relationship between chewing ability and lifestyle-related diseases, previous studies have reported relationships between periodontal disease and lifestyle-related diseases.[24,25] Among them, one analysis of national data found that individuals aged 18–64 years with severe periodontitis have a higher risk of poorer glycemic control than those without severe periodontitis, but could not confirm the existence of this relationship among individuals aged over 65 years.[26] These results might indicate that despite the strong focus on examination of lifestyle-related diseases, it does not have such a strong impact on oral health, especially among the older-elderly population.

**Table 3** Comparison of food diversity score and frequency of food intake in 11 food groups between elderly with low and high chewing ability

| | Chewing ability | | *P*-value |
|---|---|---|---|
| | Low (score 1–3) ($n$ = 105) | High (score 4, 5) ($n$ = 164) | |
| FDSK-11 (range 0–11) | 9.8 ± 1.6 | 10.5 ± 0.8 | <0.001 |
| Frequency of food intake (range 0–4) | | | |
| Grains | 3.9 ± 0.2 | 3.9 ± 0.3 | 0.250 |
| Potato | 2.3 ± 0.6 | 2.5 ± 0.7 | 0.068 |
| Beans | 3.0 ± 0.9 | 3.3 ± 0.7 | 0.006 |
| Meat | 2.5 ± 1.1 | 2.6 ± 0.7 | 0.080 |
| Seafood | 3.0 ± 0.9 | 3.0 ± 0.8 | 0.922 |
| Egg | 2.9 ± 0.8 | 2.9 ± 0.8 | 0.700 |
| Dairy | 2.8 ± 1.2 | 2.9 ± 1.0 | 0.204 |
| Vegetables | 3.4 ± 0.7 | 3.7 ± 0.5 | 0.005 |
| Seaweed | 2.6 ± 0.9 | 3.0 ± 0.7 | <0.001 |
| Nuts | 2.1 ± 0.8 | 3.4 ± 0.7 | 0.002 |
| Fruit | 2.9 ± 0.8 | 3.0 ± 0.7 | 0.678 |

Values presented as mean ± standard deviation. Frequency of food intake in 11 food groups was assessed by the question "how often do you eat these foods in a week?" with the answer "everyday: score 4", "often (3–5 days/week): score 3", "sometimes (1–2 days/week): score 2", and "hardly eat: score 1" for each 11 food groups.
FDSK-11, 11-item Food Diversity Score Kyoto.

**Table 4** Comparison of lifestyle characteristics and prevalence of lifestyle-related diseases between elderly with low and high chewing ability

| | Chewing ability | | *P*-value |
|---|---|---|---|
| | Low (score 1–3) ($n$ = 105) | High (score 4, 5) ($n$ = 164) | |
| Lifestyle characteristics | | | |
| School year (mean ± SD) | 8.7 ± 1.8 | 9.1 ± 2.0 | 0.094 |
| Good economic status (%) | 25.5 | 31.1 | 0.387 |
| Living alone (%) | 31.6 | 23.5 | 0.103 |
| Eating alone (%) | 52.0 | 47.8 | 0.071 |
| Work or farming more than once a week (%) | 62.1 | 83.2 | <0.001 |
| Exercise more than once a week (%) | 61.2 | 75.5 | 0.032 |
| Drinking alcohol (%) | 29.7 | 37.5 | 0.225 |
| Current smoker (%) | 2.0 | 6.6 | 0.079 |
| Lifestyle-related diseases | | | |
| Hypertension (%) | 69.0 | 69.8 | 0.91 |
| Hypercholesterolemia (%) | 38.5 | 39.6 | 0.89 |
| Obesity (%) | 22.0 | 23.1 | 0.87 |
| Diabetes mellitus (%) | 13.8 | 14.6 | 0.88 |
| Diabetes mellitus & impaired glucose tolerance (%) | 31.5 | 31.3 | 1.00 |

The methods by which gum color gradation was evaluated to score chewing ability could have been a limitation that affected the results of the present study. Specifically, the determination of the color graduation and the assigning of a score between 1 and 5 was carried out by a dentist rather than a machine, as it had been in previous studies, although it is unclear whether the human eye can judge the extent of color graduation as accurately as a machine. Nevertheless, the use of only one dentist to carry out the color discrimination process ensured a certain amount of consistency among the results of the process. Furthermore, the fact that the study results agreed with those of previous studies shows that this method of evaluating chewing ability is a reliable yet simple means of simultaneously assessing oral health and carrying out CGA in a community setting. The relatively small study population and the inclusion of only participants who had undergone CGA might have also been study limitations. Future studies must therefore endeavor to study larger samples that include non-CGA participants, who might be more likely to be less concerned with their dental health and might not have visited a dental clinic for a long period.

In conclusion, the study results show that low chewing ability, as evaluated by using color-changeable gum, is associated with lower ability to carry out ADL, lower cognitive functioning, higher risk of depression, and greater food insufficiency in the community-dwelling elderly population. As such, more attention should be paid to assessing the chewing ability of elderly persons, in relation to assessing comprehensive geriatric functions in community settings.

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## Disclosure statement

No conflict of interest to declare.

## References

1 Kimura Y, Wada T, Okumiya K *et al*. Community-dwelling elderly with chewing difficulty are more disabled, depressed, and have lower score in QOL. *Geriatr Gerontol Int* 2009; **9**: 102–104.
2 Matsubayashi K, Okumiya K. Field medicine: a new paradigm of geriatric medicine. *Geriatr Gerontol Int* 2012; **12**: 5–15.
3 Hayakawa I, Watanabe I, Hirano S, Nagao M, Seki T. A simple method for evaluating masticatory performance using a color-changeable chewing gum. *Int J Prosthodont* 1998; **11**: 173–176.
4 Kamiyama M, Kanazawa M, Fujinami Y, Minakuchi S. Validity and reliability of a self-implementable method to evaluate masticatory performance: use of color-changeable chewing gum and a color scale. *J Prosthodont Res* 2010; **54**: 24–28.
5 Okada K, Enoki H, Izawa S, Iguchi A, Kuzuya M. Association between masticatory performance and anthropometric measurements and nutritional status in the elderly. *Geriatr Gerontol Int* 2010; **10**: 56–63.
6 Matsubayashi K, Okumiya K, Osaki Y, Fujisawa M, Doi Y. Frailty in elderly Japanese. *Lancet* 1999; **353**: 1445.
7 Matsubayashi K, Okumiya K, Wada T, Osaki Y, Doi Y, Ozawa T. Secular improvement in self-care independence of old people living in community in Kahoku, Japan. *Lancet* 1996; **347**: 60.
8 Koyano W, Shibata H, Nakazato K *et al*. Measurement of competence: reliability and validity of the TMIG index of competence. *Arch Gerontol Geriatr* 1991; **13**: 103–116.
9 Sheikh JI, Yesavage JA. Geriatric depression scale (GDS): recent evidence and development of a shorter version. In: Brink TL, ed. *Clinical Gerontology: A Guide to Assessment and Intervention*. New York: Haworth Press, 1986; 165–173.
10 Wada T, Ishine M, Kita T *et al*. Depression screening of elderly community-dwelling Japanese. *J Am Geriatr Soc* 2003; **51**: 1328–1329.
11 Matsubayashi K, Okumiya K, Osaki Y *et al*. Quality of life of old people living in the community. *Lancet* 1997; **350**: 1521–1522.
12 Folstein MF, Folstein SE, Mchugh PR. "Mini-Mental State": a practical method for grading the cognitive state of patients for clinicians. *J Psychiatr Res* 1975; **12**: 189–198.
13 Kato S, Shimogaki H, Onodera A *et al*. Development of the revised version of Hasegawa's dementia scale [in Japanese]. *Jpn J Geriatr Psychiatry* 1991; **2**: 1339–1347.
14 Dubois B, Slachevsky A, Litvan I, Pillon B. The FAB: a frontal assessment battery at bedside. *Neurology* 2000; **55**: 1621–1626.
15 Kimura Y, Wada T, Ishine M *et al*. Food diversity is closely associated with ADL, depression and QOL in community-dwelling elderly. *J Am Geriatr Soc* 2009; **57**: 922–924.
16 Locker D. Changes in chewing ability with ageing: a 7-year study of older adults. *J Oral Rehabil* 2002; **29**: 1021–1029.
17 Morley JE. Decreased food intake with aging. *J Gerontol A Biol Sci Med Sci* 2001; **56**: 81–88.
18 Arrivé E, Letenneur L, Matharan F *et al*. Oral health condition of French elderly and risk of dementia: a longitudinal cohort study. *Community Dent Oral Epidemiol* 2012; **40**: 230–238.
19 Miura H, Yamasaki K, Kariyasu M, Miura K, Sumi Y. Relationship between cognitive function and mastication in elderly females. *J Oral Rehabil* 2003; **30**: 808–811.
20 Kant AK, Schatzkin A, Harris TB, Ziegler RG, Block G. Dietary diversity and subsequent mortality in the First National Health and Nutrition Examination Survey Epidemiologic Follow-up Study. *Am J Clin Nutr* 1933; **57**: 434–440.
21 Yoshihara A, Watanabe R, Hanada N, Miyazaki H. A longitudinal study of the relationship between diet intake and dental caries and periodontal disease in elderly Japanese subjects. *Gerodontology* 2009; **26**: 130–136.

22 Yamaga T, Yoshihara A, Ando Y *et al*. Relationship between dental occlusion and physical fitness in an elderly population. *J Gerontol A Biol Sci Med Sci* 2002; **57**: M616–M620.
23 Okuyama N, Yamaga T, Yoshihara A *et al*. Influence of dental occlusion on physical fitness decline in a healthy Japanese elderly population. *Arch Gerontol Geriatr* 2011; **52**: 172–176.
24 Soskolne WA. Epidemiological and clinical aspects of periodontal diseases in diabetics. *Ann Periodontol* 1998; **3**: 3–12.
25 Scannapieco FA, Bush RB. Associations between periodontal disease and risk for atherosclerosis, cardiovascular disease, and stroke. A systematic review. *Ann Periodontol* 2003; **8**: 38–53.
26 Taylor GW, Loesche WJ, Terpenning MS. Impact of oral diseases on systemic health in the elderly: diabetes mellitus and aspiration pneumonia. *J Public Health Dent* 2000; **60**: 313–320.