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Poor Chewing Ability Is Associated with Lower Mucosal Moisture in Elderly Individuals

Tetsuko Shinkawa,[1] Naomi Hayashida,[1] Kurumi Mori,[1] Keiichi Washio,[1] Kanami Hashiguchi,[1] Yasuyuki Taira,[1] Michiko Morishita[1] and Noboru Takamura[1]

[1]Department of Radiation Epidemiology, Nagasaki University Graduate School of Biomedical Sciences, Nagasaki, Japan

Oral dryness is common among aging individuals and its objective evaluation is an important issue for improving their oral health. In the present study, we measured the objective mucosal moisture in elderly individuals with a moisture checker and evaluated its relation with laboratory findings and subjective oral status. The subjects were 502 adults (244 men and 258 women), with a mean age of 72.3 ± 6.7 years, who participated in a regular medical screening program in Nagasaki Prefecture, Japan. We evaluated the moisture of the oral mucosa by measuring the weight percentage of water content in the oral epithelium, subjective oral dryness, self-assessed chewing ability ["good" ("able to chew all foods") or "poor" ("able to chew soft foods only" and "unable to chew any foods")], and laboratory findings. The values obtained with a moisture checker, which represent objective oral mucosal moisture, were significantly lower in women with poor chewing ability than those with good chewing ability (28.2 ± 2.4% vs. 29.2 ± 2.0%, $p = 0.004$) and in all subjects (28.4 ± 2.4% vs. 29.1 ± 2.0%, $p = 0.004$), but not in men (28.6 ± 2.5% vs. 29.0 ± 2.0%, $p = 0.27$). When multiple logistic regression analysis was performed on confounding factors, older age (OR: 1.24, $p = 0.015$), women (OR: 1.70, $p = 0.016$), and anemia (OR: 1.96, $p = 0.030$) were significantly associated with self-assessed chewing ability. Our current study indicates that poor chewing ability is associated with lower mucosal moisture in elderly individuals. ——— chewing ability; dry mouth; elderly; mucosal moisture; screening.

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Oral dryness (dry mouth) is common in aging populations. It is often due to the side effects of various medications, irradiation of the head and neck, stress, and systemic diseases such as Sjögren syndrome (Fox et al. 1985; Fox and Saito 1994; Fox 1997). In community-dwelling elderly individuals, the prevalence of oral dryness was reported to be from 13 to 39% (Billings et al. 1996; Ikebe et al. 2002; Hida et al. 2008). Because saliva plays an important role in the preservation and maintenance of oral health and function, objective evaluation of the flow rate of saliva as well as subjective evaluation of dry mouth is an important issue for improving the oral health status of elderly individuals. It is important to develop effective and convenient devices for screening the flow rate of saliva, because present examination methods are relatively tedious (Longman et al. 2000).

Recently, Yamada et al. (2005) evaluated objective oral mucosal moisture and confirmed that a normal salivation group showed significantly higher values than those of a hyposalivation group. Also, Sugiura et al. (2008) screened patients undergoing hematopoietic cell transplantation and found that throughout the examination period, patient group showed significantly lower mucosal moisture compared to normal controls. Although these results evaluated lower mucosal moisture in certain pathological conditions, objective evaluation of in general elderly population has not been reported.

Thus, we screened mucosal moisture in elderly individuals and evaluated with laboratory findings and subjective oral status, in order to clarify the factors which associated with mucosal moisture.

Methods

Subjects

Before this study began, ethical approval was obtained from the ethics committee of Nagasaki University (project registration number: 08122516). The study was conducted during a regular medical screening program for individuals more than 64 years old residing in Nagayo Town, Nagasaki Prefecture, Japan. Elderly individuals with swallowing difficulty and a past history of severe cerebrovascular diseases were excluded from the study. After obtaining informed consent, we enrolled 523 Japanese participants in the study. Because insufficient data were obtained from 21 subjects, we analyzed data

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Correspondence: Naomi Hayashida, M.D., Ph.D., Department of Radiation Epidemiology, Nagasaki University Graduate School of Biomedical Sciences, 1-12-4 Sakamoto, Nagasaki 852-8523, Japan.

e-mail: naomin@nagasaki-u.ac.jp

from 502 participants (244 men and 258 women, age 72.3 ± 6.7 years).

Evaluation of subjective oral status

Participants were asked about their self-assessed chewing ability and were instructed to select one of the three following responses: "able to chew all foods", "able to chew soft foods only," and "unable to chew any foods". Chewing ability was classified as good ("able to chew all foods") or poor ("able to chew soft foods only" and "unable to chew any foods"). Similarly, swallowing ability was classified as good ("able to swallow all foods") or poor ("able to swallow soft foods only" and "unable to swallow any foods") and oral dryness was classified as good ("never feel oral dryness") or poor ("occasionally feel oral dryness" or "always feel oral dryness").

Data collection and laboratory measurement

Blood samples were collected from each participant after fasting overnight. Intake of water was also prohibited. Hemoglobin (Hb; normal range, 13.5-17.6 g/dL in men and 11.3-15.2 g/dL in women), hematocrit (Ht; normal range, 39.8-51.8% in men and 33.4-44.9% in women), high-density lipoprotein-cholesterol (HDL-C; normal range, 40-86 g/L in men and 40-96 g/L in women), and hemoglobin A_{1c} (HbA_{1c}; normal range, 4.3-5.8%) were measured by standard laboratory procedures. Anti-nuclear antibody was measured by the fluorescent antibody method. For multiple logistic regression analysis, anemia was defined as Hb < 13.6 g/dL in men and < 11.2 g/dL in women.

Assessment of moisture of oral mucosa

The moisture of the oral mucosa was measured using a Moisture Checker for Mucus (MCM). The device was modified from a Moisture Checker of the skin (MC; Scalar Co., Ltd., Tokyo, Japan) to be applied to the oral mucosa (Yamada et al. 2005). Modification was only made to the external form; the piece from the neck to the sensor was lengthened to be able to insert it into the mouth. This device was designed to measure the weight percentage of water content in the mucosa with a measurement depth of 30 μm by touching the sensor to the oral mucosa for a few seconds (Sugiura et al. 2008). The MCM values were obtained after mouth rinsing, which was conducted several times with 100 ml of mineral water. Because MCM measures not only water content of the mucosa, but also surface water on the mucosa, in order to measure the real content of mucosa, water on the surface of the mucosa should be completely removed first (Yamada et al. 2005). Therefore, we chose rinsing to create the same measurement conditions.

The MCM values were measured at the right buccal mucosa three times for each participant with a pressure about 200 g/cm^2 and the median value was used for the following analysis. Sensor covers were used in all cases so that the device did not directly contact participants' buccal mucosa.

Two nurses (T.S. and K.H.) measured the degree of moisture with MCM. Before the measurement, they confirmed a pressure of 200 g/cm^2 by a scale. Intra-observer variation of MCM value (T.S., n = 382) was 0.65 ($p < 0.01$) and inter-observer variation (K.H. vs. T.S., n = 16) was 0.65 ($p < 0.01$). According to a previous study (Yamada et al. 2005), we defined the cut-off point of the dry mouth as 28.3% of the MCM value.

Statistical analysis

Results are expressed as mean ± standard deviation, and differences between men and women were evaluated using the t-test. Subjective oral status reports between men and women were compared by the χ^2-test. The relationship between MCM values and subjective oral status and that between subjective oral status and laboratory examinations were evaluated by the t-test and analysis of covariance for adjustment by age. Multiple logistic regression analysis was performed to assess the effects of each variable on subjective chewing ability and odds ratio (OR) and its 95% confidence interval (95% CI) were calculated. All statistical analyses were performed using SPSS software, v. 17.0 for Windows (SPSS Japan, Tokyo, Japan).

Results

Characteristics of the study participants are shown in Table 1. The mean age of the women (73.0 ± 7.1 years) was significantly older than that of the men (71.8 ± 5.9 years, $p = 0.041$). Hemoglobin and hematocrit were significantly higher in men than in women (14.4 ± 1.3 g/dL vs. 13.0 ± 1.2 g/dL, $p < 0.001$ and 44.2 ± 3.4% vs. 40.8 ± 3.3%, $p < 0.001$, respectively). Also, the percentage with poor self-assessed chewing ability was higher in women (30.6%) than in men (22.5%, $p = 0.041$). On the other hand, there was no difference in BMI between men and women (24.0 ± 2.8 vs. 23.9 ± 3.4, $p = 0.62$). Also, there was no difference in MCM values between men and women (28.9 ± 2.2% vs. 28.9 ± 2.2%, $p = 0.98$).

Table 1. Basic characteristics of study participants.

Variable	Men (n = 244)	Women (n = 258)	All (n = 502)	p Value
Age (years)	71.8 ± 5.9	73.0 ± 7.1	72.4 ± 6.5	0.041
BMI (kg/m^2)	24.0 ± 2.8	23.9 ± 3.4	23.9 ± 3.1	0.62
Hb (g/dL)	14.4 ± 1.3	13.0 ± 1.2	13.7 ± 1.4	< 0.001
Ht (%)	44.2 ± 3.4	40.8 ± 3.3	42.4 ± 3.7	< 0.001
HDL-C (g/L)	53.6 ± 13.6	59.1 ± 15.2	56.5 ± 14.7	< 0.001
HbA_{1c} (%)	5.5 ± 0.7	5.4 ± 0.6	5.4 ± 0.7	0.31
MCM value (%)	28.9 ± 2.2	28.9 ± 2.2	28.9 ± 2.2	0.98
Self-assessed chewing ability, poor (%)	55 (22.5%)	79 (30.6%)	134 (26.7%)	0.041
Self-assessed swallowing ability, poor (%)	13 (5.3%)	18 (7.0%)	31 (6.2%)	0.66
Oral dryness, poor (%)	135 (55.3%)	146 (56.6%)	281 (56.0%)	0.86

Table 2. MCM values and subjective oral conditions.

	MCM values (%)			
Variable	Poor	Good	p	p, age adjusted
Chewing ability				
Men	28.6 ± 2.5	29.0 ± 2.0	0.27	0.20
Women	28.2 ± 2.4	29.2 ± 2.0	0.004	0.005
All	28.4 ± 2.4	29.1 ± 2.0	0.004	0.002
Swallowing ability				
Men	29.4 ± 2.9	28.8 ± 2.1	0.48	0.40
Women	29.4 ± 2.2	28.9 ± 2.2	0.37	0.17
All	29.4 ± 2.5	28.8 ± 2.1	0.25	0.11
Oral dryness				
Men	28.9 ± 2.2	28.8 ± 2.0	0.83	0.75
Women	29.0 ± 2.1	28.7 ± 2.2	0.32	0.41
All	28.9 ± 2.2	28.8 ± 2.1	0.38	0.45

Table 3. Relationship between chewing ability and other variables.

Variable	Good	Poor	p Value
Age (years)	71.8 ± 6.4	74.1 ± 6.7	0.001
Sex (men/women)	189/179	55/79	0.040
RBC (/μL)	446.1 ± 42.9	435.3 ± 43.4	0.014
Hb (g/dL)	13.8 ± 1.4	13.4 ± 1.4	0.013
Ht (%)	42.7 ± 3.7	41.8 ± 3.8	0.021
HDL-C (g/L)	56.2 ± 14.9	57.1 ± 14.1	0.54
HbA_{1c} (%)	5.4 ± 0.6	5.5 ± 0.7	0.15
ANA (%)	65/368 (17.7)	33/134 (24.6)	0.098

ANA, anti-nuclear antibody.

When we divide all participants into quartiles according to their MCM values, no differences in Hb, Ht, HDL-C, and HbA_{1c} were observed between each quartile (data not shown). Also, no significant differences were seen in the frequencies of chewing ability ($p = 0.13$), swallowing ability ($p = 0.10$), and oral dryness ($p = 0.39$). On the other hand, MCM values with subjective poor chewing ability were significantly lower than MCM values with good chewing ability in women (28.2 ± 2.4% vs. 29.2 ± 2.0%, p = 0.004) and in all subjects (28.4 ± 2.4% vs. 29.1 ± 2.0%, p = 0.004), but not in men (28.6 ± 2.5% vs. 29.0 ± 2.0%, p = 0.27) (Table 2). These significances still remained after the adjustment by age. No significant difference in MCM values was observed in other subjective oral conditions, i.e., swallowing ability and oral dryness.

Because we identified that subjective chewing ability is a key factor for the determination of moisture in oral mucosa, we evaluated the relationships between chewing ability and other variables (Table 3). In subjects with poor chewing ability, the ratio of women was significantly higher compared to that in subjects with good chewing ability (59.0% vs. 48.6%, $p = 0.001$). Also, Hb (13.8 ± 1.4 g/dL vs. 13.4 ± 1.4 g/dL, $p = 0.013$) and Ht (41.8 ± 3.8% vs. 42.7 ± 3.7%, $p = 0.021$) were significantly lower in subjects with poor chewing ability than in those with good chewing ability. Frequency of positive anti-nuclear antibody was not significantly higher in subjects with poor chewing ability compared to subjects with good chewing ability (24.6% vs. 17.7%, $p = 0.098$). When multiple logistic regression analysis was performed with confounding factors, older age (OR: 1.24, $p = 0.015$), women (OR: 1.70, $p = 0.016$), and anemia (OR: 1.96, $p = 0.030$) were significantly associated with subjective chewing ability (Table 4).

Discussion

In this cross-sectional study, we screened objective mucosal moisture in elderly adults and found that subjective chewing ability, another objective variable, is a key factor for the determination of mucosal moisture. On the other hand, age and laboratory findings such as glucose metabolism and dyslipidemia were not associated with mucosal moisture. Furthermore, we identified that age, sex, and anemia are independently associated with subjective chewing ability. These results suggest that mucosal moisture is closely associated with subjective chewing ability in elderly individuals.

Table 4. Odds ratio (OR) 95% confidence interval (CI) for chewing ability, as assessed using multiple logistic regression analysis.

Variable	Unit	OR	95% CI	*p* Value
Age (years)	+ 5	1.24	1.04 - 1.48	0.015
Sex	Women/Men	1.70	1.10 - 2.61	0.016
Anemia	Yes/No	1.96	1.07 - 3.60	0.030
Anti-nuclear antibody	Positive/Negative	0.96	0.64 - 1.46	0.86

The subjective measure of mucosal moisture has usually been based on unstimulated salivary flow rate (Sreebny and Valdini 1988; Navazesh et al. 1992) or stimulated salivary flow rate (Närhi et al. 1999; Osterberg et al. 1984). Previous methods for the measurement of unstimulated salivary flow rate needed a longer time for collection of saliva because of low flow rates (Ikebe et al. 2002). In addition, because resting salivary flow rates are dependent on the time of day (Dawes 1972) and the physical and mental condition of the subject (Bergdahl and Bergdahl 2001) and take longer to collect because of low flow rates, stimulated saliva flow rather than unstimulated saliva flow has been used in studies of a large population. In this study, we used MCM, a novel device for the measurement of unstimulated oral moisture that is available to obtain results within a few seconds. Furthermore, we measured MCM values three times in each subject and confirmed relatively high correlations between the first and second measurements ($r = 0.64$, $p < 0.001$), second and third measurements ($r = 0.68$, $p < 0.001$), and first and third measurements ($r = 0.60$, $p < 0.001$). These results suggest that MCM is available for the screening of unstimulated mucosal moisture in the general population.

Also, we showed that oral mucosal moisture with subjective poor chewing ability was significantly lower than those of patients with good chewing ability. Foerster et al. (1998) indicated a significant relationship between reports of dry mouth and self-assessed chewing difficulty. Ikebe et al. (2001) examined the prevalence of perceived dry mouth among a group of independently-living elderly persons in Japan and found that self-assessed chewing ability was associated with subjective dry mouth during eating. Furthermore, Yeh et al. (2000) and Ikebe et al. (2007) recently showed that poor chewing ability is associated with a decline in stimulated whole salivary flow rate independent of sex and medication in healthy elderly individuals. In this study, we showed that unstimulated mucosal moisture is also associated with self-assessed chewing ability. Although we could not show cause-effect relationships due to the cross-sectional design, it is difficult to assume that mucosal moisture influences chewing ability (Ikebe et al. 2007). Conversely, it appears more plausible that reduced chewing ability influences mucosal moisture. Further longitudinal studies are needed to clarify the effect of poor chewing ability on mucosal moisture.

Interestingly, we showed that poor chewing ability is independently associated with anemia, as well as aging and women. Peek et al. (2002) performed a longitudinal study to evaluate the relationship between subjective chewing ability and demographic measures and found that elderly individuals, women, African Americans, and individuals living in rural areas were more likely to develop chewing difficulty. Furthermore, it was reported that elderly individuals having a compromised dentition or wearing complete dentures consumed lower levels of proteins and fiber, as well as nutrients such as iron and folic acid, which are essentially needed for the formation of erythrocytes (Ranta et al. 1988; Budtz-Jørgensen et al. 2001). Our current results suggest that the lower intake of nutrients in elderly individuals with poor chewing ability may cause the progression of anemia.

There are several limitations in this study. We could not evaluate the dental status of the study participants. Because a significant association between the perception of dry mouth among a group of denture wearers with oral symptoms and oral function was previously reported (Feine and Lund 2006), further investigations that include the screening of dental status are needed to establish the strategy for the evaluation of objective mucosal moisture for screening. Also, we could not collect information on the number of medications of the study participants. Because one of the most common side effects of many drugs, such as antidepressants, antihistamines, and diuretics, is dry mouth (Dodds et al. 2005), the effects of drugs on mucosal moisture should be carefully considered. In addition, we could not evaluate other measurements of hydration, such as urine specific gravity, and could not fully validate self-assessable indices, such as chewing ability and swallowing ability.

In conclusion, we screened mucosal moisture in elderly individuals and found that poor chewing ability is closely related with lower mucosal moisture. Further studies are needed to develop a comprehensive strategy for screening mucosal moisture in elderly individuals.

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