博 士 論 文

Association between denture use and food form in older adults requiring long-term care: A multicenter cross-sectional study

（要介護高齢者における義歯使用と食形態の関連について：多施設横断研究）

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Association between denture use and food form in older adults requiring long-term care: A multicenter cross-sectional study

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Abstract

Purpose: This study aimed to determine whether denture use contributes to maintaining and improving food forms in long-term care facility (LTCFs) residents.

Methods: In 888 residents of 37 LTCFs in Japan, the following were investigated: nutritional intake status, food forms, age, sex, Barthel index (BI), clinical dementia rating (CDR), number of teeth present, number of occlusal supports, swallowing function, and use of dentures. Among all residents, those who were well-nourished and had ≤9 occlusal supports were analyzed. Based on standardized criteria, the food forms consumed by the subjects were divided into two groups: dysphagia and normal diet, which were further classified into four levels. Analysis was performed using a generalized estimation equation with the four levels of food forms as dependent variables and age, sex, BI, CDR, presence of dysphagia, number of teeth present, and use of dentures as independent variables.

Results: The final analysis included 622 (70.0%) residents. Of these, 380 (61.1%) used dentures. The analyses revealed that food form was significantly associated with age (adjusted odds ratio [OR], 0.98), BI (OR, 1.04), number of teeth present (OR, 1.03), presence of dysphagia (OR, 0.44), and use of dentures (OR, 2.82).

Conclusion: Denture use was associated with food forms among Japanese LTCF residents. This indicates that the use of dentures is related to the maintenance of food forms, even in the elderly who participate in few activities of daily living, have reduced cognitive function, and require long-term care.

Keywords: Cross-sectional study, Denture use, Food forms, Older adults requiring long-term care, Swallowing function

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1. Introduction

A dysphagia diet is provided to 26–67% of residents in long-term care facilities (LTCFs) to prevent aspiration[1,2]. However, a dysphagia diet may have a poor appearance, taste, and reduced nutritional value, which may cause dehydration[1,3–6]. Furthermore, the

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intake of a dysphagia diet is associated with a lower quality of life (QOL)[7]. Therefore, maintaining and improving food forms in dysphagia diets is essential to maintain and improve the health and QOL of LTCF residents.

In LTCF residents, the efficiency of the masticatory function is better in those with partial dentures than in those without partial dentures[8]. Moreover, when food is divided into normal and dysphagia diets, the number of teeth present and tooth contact pairs, natural or artificial, significantly affect the maintenance of food forms[9].

Until 2013, each institution and region used different terms to describe identical dysphagia diets in Japan[10]. Therefore, the relationship between food forms assessed using standardized criteria and the use of dentures has not been fully elucidated. Furthermore, a decline in activities of daily living (ADL) and cognitive function reportedly makes the use of dentures difficult[11]. However, few studies have examined whether dentures are associated with food forms even in LTCF residents with a decline in ADL and cognitive function[9].

Many nursing home residents do not use dentures despite needing them[11–14], which is likely related to poorly fitting dentures[15]. Other factors, such as denture mismanagement, loss of dentures, and lack of oral care services, may also make denture use difficult for elderly residents in need of care[16]. Furthermore, it can be assumed that there is little cooperation between oral healthcare providers and nursing staff[17–24]. If the results of this study indicate that the use of dentures could maintain food form even in LTCF residents with a decline in ADL and cognitive function, it might be possible to promote the importance of providing prosthetic treatment to the elderly who require long-term care and support the use of dentures in cooperation with caregivers. Moreover, the use of dentures may improve QOL and the nutritional status of the elderly[25–28]. The use of dentures may also reduce mortality risk[29].

Therefore, we hypothesized that the use of dentures might be related to the maintenance of food forms, even in LTCF residents with a decline in ADL and cognitive function. Consequently, we conducted a cross-sectional survey on the use of dentures and food forms in Japanese LTCF residents to examine this relationship.

2. Materials and methods

2.1. Study design

This was a cross-sectional study including Japanese LTCF residents.

2.2. Participants

A workshop was held for 30 specially appointed committee members of the Japanese Society of Gerodontology to explain the study content and establish unified evaluation criteria for survey items that were repeatedly standardized until all evaluations were in perfect agreement to ensure consistent assessments. Subsequently, each committee member explained the study content to the institution's chief and the staff of their corresponding facilities. For this study, the members of the appointed committee collaborated with 37 facilities in 17 regions. In September 2018, facility staff members who collaborated in this study with participants and their families were asked to confirm their willingness to participate in advance. In cases where it was possible to obtain consent from a participating LTCF resident, the researcher directly explained the study contents and obtained written consent for participation in the study from the LTCF resident. In cases where it was difficult to obtain consent from potential study participants, their families received a written explanation of the study to obtain written consent from them. Written consent was obtained from 888 residents and their families to participate in the study, and the study was conducted between October 2018 and February 2019. This study was approved by the ethics committee of the Japanese Society of Gerodontology (approval number: 2018-1) and the epidemiological research ethics committee of Hokkaido University (approval number: 2020-4). This study was conducted following the ethical principles of the Declaration of Helsinki.

2.3. Survey items

During the survey, the research members provided training on the evaluation of survey items to all nurses and registered dietitians of the included institutions, and the evaluation criteria were unified. The questionnaires were then distributed to the attending nurses and registered dietitians of LTCF residents, and basic information (e.g., age, sex, body mass index [BMI], and recent serum albumin levels) as well as information on physical, cognitive, and swallowing function, nutritional intake status, and food form were collected.

2.3.1. Questionnaire

2.3.1.1. Basic information

The participants' age, sex, BMI, recent serum albumin levels, nutritional methods (including oral, enteral, and intravenous nutrition), and use of dentures during meals were transcribed from nursing records by the nurses and registered dietitians in charge.

2.3.1.2. Physical and cognitive functions

A charge nurse evaluated physical function using the Barthel index (BI)[30,31]. Cognitive function was assessed using the clinical dementia rating (CDR)[32] by nurses from the included institutions who received prior training from co-investigators on the standardized assessment criteria; the Japanese version of the CDR scoring sheet was used[33]. Finally, a Japanese psychiatrist specializing in dementia, certified as a dementia specialist in Japan, checked all assessments and determined the final CDR score.

2.3.1.3 Nutritional intake status

Each facility's registered dietitian calculated the average daily total oral energy intake (kcal/day) for each resident during the previous week by referring to the amount of food provided by the dietitians and the amount of remaining food visually checked by the nurses and caregivers[34–38].

Participants were classified into oral and parenteral intake groups according to enteral and intravenous administration routes for nutrition. The oral intake group was divided into well-nourished and poorly nourished groups. The residents were assigned to the poorly nourished group if their average daily total oral energy intake was <75% or the well-nourished group if their average daily total oral energy intake was ≥75%. The well-nourished group was further classified into two subgroups: a group with ≥10 occlusal supports and another with ≤9 occlusal supports. The definition of an occlusal support has been elaborated subsequently.

2.3.1.4. Food forms

The dietitian in charge classified dysphagia diets according to the Japanese Dysphagia Diet 2013 (JDD 2013) guidelines[39] proposed by the Japanese Society of Dysphagia Rehabilitation. Dysphagia diets were classified into five codes (0 to 4), with higher codes indicating dysphagia diets that were closer to a normal diet. Although a normal diet is stiffer than a dysphagia diet, it is classified into two food forms. The lower level comprised soft, tender, and easily chewable food forms or food forms that had been modified (e.g., chopped or thickened with starch). A higher level represented normal meals that were not modified for easier consumption. Consequently, dysphagia and normal diets were classified into the following four levels: food form 1, JDD 2013 level <2-2; food form 2, JDD 2013 levels 3 and 4; food form 3, soft normal diet (including food that can be chewed with little effort) or normal modified diet; food form 4, normal diet that has not been modified to be soft and easy to eat.

2.3.1.5. Swallowing function

The swallowing function of the participants was assessed using a questionnaire for dysphagia screening developed by Ohkuma et al.[40]. This questionnaire consists of 15 items reflecting the history of pneumonia; nutritional status; oral, pharyngeal, and esophageal function; and epiglottis function. Each question was evaluated using a three-point scale: "A, severe symptoms;" "B, mild symptoms;" and "C, no symptoms." Based on previous studies, we considered that a participant had "dysphagia" if any of the 15 items were answered with "A" and "no dysphagia" if all items were answered with "B" or "C"[40–42].

2.3.2. Assessments

A survey was conducted by 30 dentists and dental hygienists who were pretrained using the agreed-upon uniform evaluation criteria. The dentists and dental hygienists were unaware of the food form consumed by the residents. "Number of teeth present" was defined as the number of erupted teeth in the oral cavity, excluding roots with collapsed crowns and teeth with a score of 3 according to Miller's mobility index[43,44]. When the crown structure of the tooth is lost and only a residual root is present, it is considered the "stump of the tooth" and corresponds to "C4" used in Japanese dental examinations (e.g., school dental examinations and community health examinations) to describe carious lesions. In Japanese dental examinations, caries is diagnosed according to the degree of substantial loss of the coronal tooth structure. According to this standard, the crown structure is almost completely lost and only a residual root is present in a C4 tooth[45–47]. The dentists and dental hygienists surveyed residents or their caregivers about their use of dentures. The "number of occlusal supports" was defined as the number of supports in which the same type of teeth on the ipsilateral upper and lower jaws belonged to one of the following combinations: tooth present and tooth present; tooth present and implant; tooth present and pontic; and pontic and pontic. Roots with collapsed crowns, teeth affected by severe periodontitis, and wisdom teeth were excluded from the study.

2.4. Statistical analysis

Categorical variables were analyzed using the chi-square test for item-specific comparisons between the well-nourished and poorly nourished groups. Categorical variables with two terms were tested using the Cochran–Armitage trend test, and variables with three or more categories were tested using the Kruskal–Wallis test. Continuous variables were analyzed using the independent *t*-test or Mann–Whitney U test, considering normality. Subsequently, the items expected to have trends or differences between residents with occlusal supports ≤9 who ate any of the four food forms, considered continuous variables, were tested using the Jonckheere–Terpstra trend test.

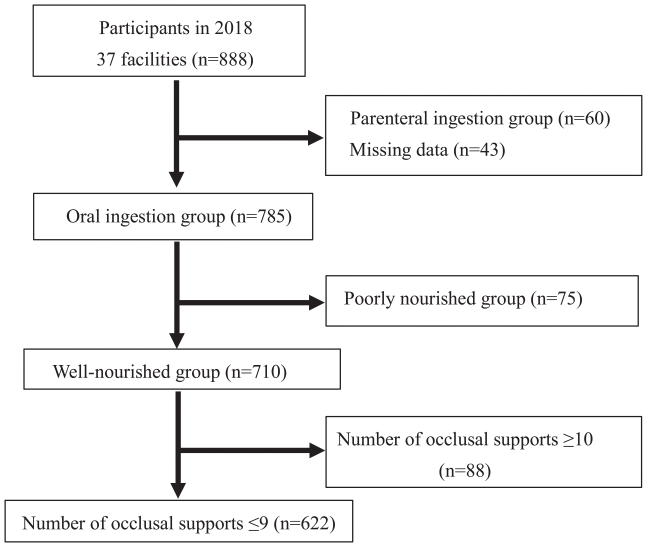

Fig. 1. Analysis of target selection. Groups excluded from the analysis are indicated by the right-pointing arrows. Groups included in the analysis are indicated by the downward-pointing arrows.

A multivariate analysis was performed in residents with ≤9 occlusal supports to examine the relationship between food forms and the use of dentures. Based on previous test results, the four aforementioned levels of food forms were used as dependent variables, and sex, age, BI, CDR, number of teeth present, dysphagia, and use of dentures were independent variables. In multivariate analysis, adjusted odds ratios (ORs) with 95% confidence intervals (CIs) were obtained using a generalized estimation equation, considering that the corresponding data had a hierarchical structure across multiple facilities. All statistical analyses were performed with SPSS Statistics version 26 (IBM, Armonk, NY, USA), and a p-value <0.05 was considered statistically significant.

3. Results

Of the 888 residents investigated using cross-sectional surveys, 785 were included in the analysis: 176 males and 609 females, with a mean age of 86.6 years and a standard deviation of 7.8 years. We excluded 60 residents who received parenteral nutrition and 43 participants with missing data on age, BMI, nutritional intake status, nutritional methods, food forms, BI, CDR, serum albumin levels, swallowing function, use of dentures, or oral condition, including the number of teeth present, prosthetic teeth, and missing teeth (**Fig. 1**).

The characteristics of the participants were as follows: age: median, 87.0 years and interquartile range (IQR), 82–93 years; BI: median, 30. 0 and IQR, 10.0–50.0; CDR 0 and 0.5: 74 (9.4%); CDR 1: 149 (19.0%); CDR 2: 235 (29.9%); CDR 3: 327 (41.7%); number of teeth present:

Table 1. Characteristics of the study participants and comparison between the well-nourished and poorly nourished groups.

	Nutritional status (n=785)														
	Overall (n=785)					Well-nourished (n=710)					Poorly nourished (n=75)				
	Mean ± SD n (%)		Median	Q1	Q3	Mean ± SD n (%)		Median	Q1	Q3	Mean ± SD n (%)		Median	Q1	Q3	p-value
Age (years)	86.6 ±	7.8	87.0	82.0	92.5	86.4 ±	7.8	87.0	82.0	92.0	88.6 ±	7.6	89.0	85.0	94.0	0.020
Sex (female)	609	(77.6)				544	(76.6)				65	(86.7)				0.047
Body mass index (kg/m^2)	20.4 ±	3.6	20.1	17.8	22.7	20.6 ±	3.6	20.4	18.1	22.8	18.3 ±	3.0	17.8	16.1	20.3	<0.001
Barthel index	32.6 ±	26.0	30.0	10.0	50.0	33.6 ±	26.0	30.0	10.0	50.0	23.0 ±	24.2	15.0	0.0	40.0	<0.001
Serum albumin level (g/dL)	3.5 ±	0.4	3.5	3.2	3.8	3.5 ±	0.4	3.5	3.2	3.8	3.3 ±	0.6	3.2	3.0	3.5	<0.001
Number of teeth present	8.3 ±	8.8	5.0	0.0	15.0	8.5 ±	8.9	6.0	0.0	16.0	6.7 ±	7.6	4.0	0.0	13.0	0.140
Clinical dementia rating																
0, 0.5	74	(9.4)				69	(9.7)				5	(6.7)				0.001
1	149	(19.0)				143	(20.1)				6	(8.0)				
2	235	(29.9)				216	(30.4)				19	(25.3)				
3	327	(41.7)				282	(39.7)				45	(60.0)				
Food form																
4: Regular diet	154	(19.6)				147	(20.7)				7	(9.3)				0.001
3: Processed diet	309	(39.4)				281	(39.6)				28	(37.3)				
2: Swallowing diet (3,4)	194	(24.7)				176	(24.8)				18	(24.0)				
1: Swallowing diet (2-2 or loss)	128	(16.3)				106	(14.9)				22	(29.3)				

Serum albumin levels only in recorded cases (overall: n=559, well-nourished group: n=501, and poorly nourished group: n=58). Categorical variables are shown as numbers (percentage) and were analyzed using the chi-square test. Statistical significance was set at p<0.05. Continuous variables, including age, body mass index, and serum albumin levels, were analyzed using the t-test. Continuous variables, including Barthel index, clinical dementia rating, the number of teeth present, and food form divided into four levels, were analyzed using the Mann–Whitney U test. Statistical significance was set at p<0.05. Q1, first quartile; Q3, third quartile; and SD, standard deviation.

median, 5 and IQR, 0–15; and number of occlusal supports: median, 0 and IQR, 0–4. No combinations of implants, pontics, or implants were found in the study participants. There were 710 (90.4%) and 75 (9.6%) residents in the well-nourished and poorly nourished groups, respectively. A comparison of both groups showed that the well-nourished group had significantly higher BMI, BI, and serum albumin levels, as well as significantly lower age and proportion of females than the poorly nourished group. Moreover, the two groups differed significantly in CDR and food form proportions (**Table 1**).

Of the 710 residents in the well-nourished group, 88 (12.4%) had ≥10 occlusal supports, and 622 (87.6%) had ≤9 occlusal supports. Those with ≥10 occlusal supports were significantly younger and had a significantly higher BMI and number of teeth present than those with ≤9 occlusal supports. Moreover, there was a significant difference in the proportion of food forms between those with ≥10 and ≤9 occlusal supports (**Table 2**).

Of the 622 residents with ≤9 occlusal supports, 99 (15.9%) ate food form 1, 164 (26.4%) ate food form 2, 244 (39.2%) ate food form 3, and 115 (18.5%) ate food form 4. As food forms approached a normal diet, age and the rate of dysphagia decreased significantly, while BI, the number of teeth present, and the rate of use of dentures increased significantly. Moreover, CDR was significantly different between the four food forms (**Table 3**).

Analyses using generalized estimation equations with the aforementioned four levels of food forms as dependent variables revealed that age (adjusted OR, 0.98; 95% CI, 0.96–1.00; p = 0.037), BI (OR, 1.04; 95% CI,1.03–1.05; p < 0.001), number of teeth present (OR, 1.03; 95% CI, 1.01–1.05; p = 0.001), use of dentures (0: not used vs. 1: used; OR, 2.82; 95% CI, 2.12–3.73; p < 0.001), and dysphagia (0: absence of dysphagia vs. 1: presence of dysphagia; OR, 0.44; 95% CI, 0.33–0.58; p < 0.001) were significantly associated with the four levels of food forms (**Table 4**). Moreover, the correlation matrix did not indicate independent variables with a correlation coefficient |r| > 0.8 (**Table S1**).

4. Discussion

This study investigated the actual food forms consumed by Japanese LTCF residents. Subsequently, we examined whether the use of dentures is related to food forms in older adults who require long-term care. We also examined other factors that are expected to be related to food forms. The results revealed that food forms closer to a normal diet were associated with increased BI, a higher number of teeth present, absence of dysphagia, and use of dentures. This indicates that the use of dentures may have contributed to the maintenance of food forms, even in residents with a decline in ADL and cognitive function.

A cross-sectional study of 639 Canadian LTCF residents reported significant associations of the four food forms (regular, soft and bite-size, minced and moist, and pureed) with ADL and cognitive performance scores[48]. Previous studies also reported that dysphagia risk, a factor that directly affects food intake, was positively correlated with modified food texture[48–50]. There was no significant

Table 2. Comparison of study participant characteristics between the occlusal support groups.

	Well-nourished group (n=710)											
	Number of occlusal supports ≥10 (n=88)						Number of occlusal supports ≤9 (n=622)					
	Mean ± SD						Mean ± SD					
	n (%)			Median	Q1	Q3	n (%)			Median	Q1	Q3	p-value
Age (yers)	83.1	±	9.0	84.5	77.3	89.0	86.8	±	7.5	87.0	82.0	92.3	<0.001
Sex (female)	66		(75.0)				478		(76.8)				0.701
Body mass idex (kg/m^2)	21.4	±	3.7	21.5	18.9	23.7	20.5	±	3.6	20.2	18.0	22.7	0.034
Barthel index	35.1	±	23.4	35.0	20.0	50.0	33.4	±	26.4	30.0	10.0	55.0	0.438
Serum albumin level (g/dL)	3.5	±	0.4	3.5	3.3	3.7	3.5	±	0.4	3.5	3.2	3.8	0.757
Number of teeth present	24.5	±	2.3	24.0	23.0	26.8	6.2	±	6.9	4.0	0.0	11.0	<0.001
Clinical dementia rating													
0, 0.5	9		(10.2)				60		(9.6)				0.101
1	23		(26.1)				120		(19.3)				
2	28		(31.8)				188		(30.2)				
3	28		(31.8)				254		(40.8)				
Food om													
4: Regular diet	32		(36.4)				115		(18.5)				<0.001
3: Processe diet	37		(42.0)				244		(39.2)				
2:Swalwing diet (3, 4)	12		(13.6)				164		(26.4)				
1: Swlowing diet (2-2 or loss)	7		(8.0)				99		(15.9)				

Serum albumin levels only in recorded cases (number of occlusal supports ≥10, n=62; and number of occlusal supports ≤9, n=439). Categorical variables are shown as numbers (percentages) and were analyzed using the chi-square test. Statistical significance was set at $p<0.05$. Continuous variables, including age, body mass index, and serum albumin level, were analyzed using the *t*-test. Continuous variables, including the Barthel index, clinical dementia rating, the number of teeth present, and food form divided into four levels, were analyzed using the Mann–Whitney U test. Statistical significance was set at $p<0.05$. Q1, first quartile; Q3, third quartile; and SD, standard deviation.

association between food forms and cognitive function between the groups in our study. However, we found significant associations between food forms and ADL, as well as food form and dysphagia risk, similar to the aforementioned Canadian study[48]. Moreover, a dysphagia diet may be chosen to prevent aspiration when masticatory and swallowing abilities decline[2]. Studies conducted on Japanese people aged ≥65 years reported that a higher level of competence in daily living and the number of teeth present were significantly associated with objective masticatory function[51]. The results of our study support these findings.

According to the correlation matrix in this study, no independent variable had a correlation coefficient of $|r| > 0.8$. Therefore, we considered the possibility of multicollinearity low, and all independent variables were included in the analysis[52]. Generally, significant confounding is present between the loss of teeth and the use of dentures. However, this was not observed in this study. This may indicate that many participants with fewer teeth had their dentures removed. Furthermore, no significant association was found between the CDR scores and food forms, possibly because ≥70% of residents had severe cognitive decline with CDR scores ≥2.

In a survey of 150 people (mean age, 82.1 years) living in nine German special nursing homes, in which 75.3% were female participants, the percentage of people with cognitive decline (CDR score ≥1) was 62.6%, and removable prosthetic devices (partial or complete dentures) were used by 57.3% of the participants[53]. In a survey of 2711 residents (mean age, 84.4 years) in 30 special nursing homes in western Canada, the proportion of females was 68.2%, the prevalence of dementia was 59.2%, and the rate of removable denture use was 55.4%[54]. According to a 2017 review of dysphagia diets, 26–67% of residents in LTCFs used a dysphagia diet[1], which was similar to our study. The rates of age, cognitive decline, and use of dentures were higher in the present study than in studies conducted in other countries. However, in Japan, the percentage of the total population of older people is 28.4% (the highest globally)[55], and the percentage of people with cognitive decline is high[56]. Furthermore, as this study focused on the use of dentures and food forms, patients who required parenteral intake and those with ≥10 occlusal supports were excluded. Accordingly, the participants in this study were similar to the general Japanese LTCF resident population.

Dietary intake was used as an index for nutritional assessment. Although BMI is commonly used, it is often difficult to measure the height and weight of the elderly, especially those who need nursing care, due to various factors such as inability to stand or deformity of the spinal column[57]. This dietary intake threshold is based on the categorizations used by the long-term care insurance available to the elderly in Japan. Consequently, if the average daily total oral energy intake is <75%, the person is categorized as poorly nourished or likely to become poorly nourished if the current diet continues[58–60]. In a nutritional study of hospitalized patients, none of the patients with an average daily total oral energy intake of 50–74% gained weight. Approximately 25% of the patients lost more than 5% of their body weight. In contrast, only a small percentage (<10%) of patients with an average daily total oral energy intake of ≥75% lost > 5% of their body weight[61].

In the present study, the stumps of teeth were not counted based on the number of teeth according to the classification of carious lesions used in dental examinations in Japan. The four categories, C1 to C4, reflect the degree of parenchymal defects in crown dentin and determine the treatment plan and prognosis[45–47]. For example, C1/C2 may lead to dental fillings and restorations, C3 may

Table 3. Comparison of study participant characteristics (number of occlusal supports ≤9) between the four food form groups.

	Food forms targeting participants with a number of occlusal supports ≤9 (n=622)																
	1: Swallowing diet (2-2 or loss) (n=99)				2: Swallowing diet (3, 4) (n=164)				3: Processed diet (n=244)				4: Regular diet (n=115)				
	Mean ± SD n (%)	Median	Q1	Q3	Mean ± SD n (%)	Median	Q1	Q3	Mean ± SD n (%)	Median	Q1	Q3	Mean ± SD n (%)	Median	Q1	Q3	Trend p-value
Age (years)	87.4 ± 6.7	87.0	83.0	92.0	88.0 ± 7.2	89.0	83.3	93.0	86.5 ± 8.0	87.0	81.3	92.0	85.5 ± 7.4	86.0	82.0	91.0	0.010
Sex (female)	76 (76.8)				131 (79.9)				187 (76.6)				84 (73.0)				0.365
Barthel index	11.6 ± 17.4	5.0	0.0	15.0	21.3 ± 19.2	15.0	5.0	35.0	38.4 ± 23.9	40.0	20.0	55.0	58.6 ± 21.6	60.0	45.0	75.0	<0.001
Clinical dementia rating																	
0, 0.5	5 (5.1)				5 (3.0)				25 (10.2)				25 (21.7)				<0.001
1	6 (6.1)				18 (11.0)				56 (23.0)				40 (34.8)				
2	17 (17.2)				50 (30.5)				84 (34.4)				37 (32.2)				
3	71 (71.7)				91 (55.5)				79 (32.4)				13 (11.3)				
Presence of dysphagia	71 (71.7)				101 (61.6)				91 (37.3)				13 (11.3)				<0.001
Number of teeth present	5.7 ± 6.7	3.0	0.0	11.0	5.2 ± 6.4	2.0	0.0	9.8	6.5 ± 6.9	5.0	0.0	11.8	7.3 ± 7.3	6.0	0.0	14.0	0.015
Using dentures	31 (31.3)				85 (51.8)				167 (68.4)				97 (84.3)				<0.001

Categorical variables (clinical dementia rating) are shown as numbers (percentages) and were analyzed using the Kruskal–Wallis test. Categorical variables, including sex, denture usage, and presence of dysphagia, are shown as numbers (percentages) and were analyzed using the Cochran–Armitage trend test. Statistical significance was set at p<0.05. Continuous variables, including age, Barthel index, and the number of teeth present, were analyzed using the Jonckheere–Terpstra trend test. Statistical significance was set at p<0.05. Q1, first quartile; Q3, third quartile; and SD, standard deviation.

Table 4. Generalized estimation equation for the four levels of food forms (n=622).

	B	SE	Wald χ^2	Adjusted odds ratio	95% CI Lower confidence limit	95% CI Upper confidence limit	p-value
Age (years)	-0.02	0.01	4.34	0.98	0.96	1.00	0.037
Male (female)	0.00	0.21	0.00	1.00	0.67	1.50	0.987
Barthel index	0.04	0.00	79.6	1.04	1.03	1.05	<0.001
Clinical dementia rating							
0, 0.5				(Reference)			
1	0.27	0.29	0.86	1.31	0.74	2.34	0.353
2	0.05	0.35	0.02	1.05	0.53	2.10	0.886
3	-0.14	0.30	0.23	0.87	0.48	1.56	0.632
Presence of dysphagia (absence of dysphagia)	-0.82	0.14	34.0	0.44	0.33	0.58	<0.001
Number of teeth present	0.03	0.01	11.4	1.03	1.01	1.05	0.001
Using dentures (not using dentures)	1.04	0.14	51.8	2.82	2.12	3.73	<0.001

A generalized estimation equation was used to analyze the following dependent variables: the four levels of food forms in well-nourished participants with ≤9 occlusal supports. Independent variables: age, sex, Barthel index, clinical dementia rating, number of teeth present, having dysphagia, and denture usage. B, unstandardized regression coefficient; SE, standard error of B; Wald χ^2, Wald statistic; and CI, confidence interval.

lead to root canal treatment, and C4 may lead to prostheses after tooth extraction[45].

The present study postulates that the use of removable prosthetic devices in the ≤9 occlusal support group is advisable. This hypothesis was based on the guidelines for oral rehabilitation described in the periodontal treatment policy published by the Japanese Society of Periodontology in 2015[62]. According to these guidelines, oral rehabilitation treatment is a generic term for a treatment process that involves occlusal treatment, restorative and prosthetic therapy, orthodontic treatment, and implant therapy to restore oral function lost due to periodontal disease. In addition to restoring proper occlusal and masticatory functions and esthetics, this treatment is critical to the long-term maintenance of periodontal tissue function. Moreover, these guidelines recommend the use of removable prosthetic devices, particularly when the number of occlusal supports is ≤9. Cocco et al.[63] defined a functional occlusal support unit as homonymous upper and lower ipsilateral teeth that combine natural teeth (i.e., healthy teeth or crown-restored treated teeth), fixed prostheses (i.e., bridge or pontic prostheses), or removable prostheses. The total number of functional occlusal support units was taken as the number of occlusal supports. However, to investigate the association between removable dentures and food forms in this study, removable prostheses and other combinations, including removable prostheses and removable prostheses, removable prostheses and natural teeth, and removable and fixed prostheses, were not counted as occlusal supports.

In Japan, doctors and nurses at LTCFs usually assess the patients' eating behaviors and determine the optimal dietary approach[64]. This also applies to the facilities included in this study. However, since the use of dentures is rarely considered in this assessment, this study was conducted. Based on the JDD 2013[10,39], which has been widely used as a standard to classify dysphagia diet stages in Japan, food forms in LTCF residents were classified into six stages, and the normal diets were divided into two stages. Considering the number of residents who fell into the eight stages of food forms, the food forms were combined into four levels. In the International Dysphagia Diet Standardization Initiative (IDDSI) framework, which is considered an international criterion for dysphagia diets[65,66], each of the dysphagia stages (1, 2, 3, and 4) is considered to correspond to the following food forms: minced and moist, soft and bite-sized, easy-to-chew, and regular diets, respectively[39,67,68]. We believe that the classification used in this study approximates that of the IDDSI framework.

Patients in the poorly nourished group were excluded from the analysis based on previous studies suggesting that if the food form provided to LTCF residents is unsuitable, their nutritional status becomes poor[69,70]. There were significant differences in age, BMI, BI, albumin level, and CDR between the well-nourished and malnourished groups. These results are similar to those of previous studies[71–73], and the well-nourished group in this study indicated that a suitable food form was provided. The exclusion of the poorly nourished group from further analyses may have created selection bias. However, since similar results were obtained in analyses including the poorly nourished group, and the poorly nourished group was much smaller than the well-nourished group (**Table S2**), we believe that the effect of excluding the poorly nourished group is insignificant.

According to the periodontal treatment policy published by the Japanese Society of Periodontology in 2015[62], well-nourished participants were divided into two groups: one with ≥10 occlusal supports and the other with ≤9 occlusal supports. The results showed significant differences in age, BMI, number of teeth present, and food forms between the groups. As the number of teeth present and occlusal supports has been reported to be associated with food avoidance[74–76], these results also support the findings of previous studies. Moreover, a low number of teeth and posterior occluding pairs are associated with a high risk of malnutrition[77–80], and our results are consistent with the results of previous studies that confirm significant differences in BMI between the groups.

The present study revealed significant differences in age, BI, the number of teeth present, dysphagia, and the use of dentures between the four levels of food forms. Moreover, a significant difference was observed in the CDR between the four levels of food forms. Greater cognitive impairment, dependence on other people to perform ADL, and risk of dysphagia have been reported to be associated with a dysphagia diet prescription for LTCF residents[38]. Additionally, it has been shown that the number of teeth present significantly affects food forms when food is divided into regular and dysphagia diets[9]. Therefore, we believe that the results of our study support those of previous studies.

The present study showed that dentures may have contributed to the maintenance of food forms, even in residents with a decline in ADL and cognitive function. However, it is undesirable to force all elderly people receiving care to use dentures because there are several reports of denture-related accidents, such as accidental ingestion, in denture users with cognitive impairment[81–84]. Furthermore, dentures can cause changes in oral sensation and decrease oropharyngeal swallowing efficiency, which is a quantitative measure of swallowing efficiency[15,85]. Second, nursing homes now focus on creating an environment in which patients can die peacefully and painlessly at the end of their lives[86]. For example, there is a movement to introduce comfort feeding only (CFO) as an oral intake at the end of dementia[87]. In CFO, the goal of feeding is not to nourish but to enjoy life. This should be determined according to the patient's condition. When patients cannot eat on their own, efforts must be made to provide oral intake with as much assistance as possible. Patients should eat what they want to eat, when they want to eat, in the amount they want to eat, and should not be forced to eat against their preference. Therefore, it is preferable that the patient is willing to use dentures; however, if the patient experiences pain from using dentures, the decision to not force the patient to use dentures can be taken.

This study has certain limitations. First, the facilities surveyed in this study are relevant to members of the Japanese Society of Gerodontology; therefore, there is bias in institutional sampling. One of the objectives of this survey was to assess the oral conditions of residents in Japanese long-term care insurance facilities. Therefore, we included as many facilities as possible during the recruitment of study participants. We analyzed data from 622 participants, which we considered a sufficient sample size according to the sample sizes of previous studies[53,88–90]. However, in some facilities, all residents participated in the study, while only residents of one unit were included in other facilities. Unfortunately, we did not have information on the number of people who had explanations about participation in the study, the number of people who declined, or the reasons for their refusal because we asked nursing home staff to indicate their willingness to participate in the study in advance. Therefore, the results of this study should be interpreted with cau-

tion due to possible selection bias. The clear purpose and content of the study could have led denture non-users and those unable to use dentures to refuse to participate in the study. However, the analysis that excludes these individuals would not overestimate the observed association because it would work toward not rejecting the null hypothesis. This is because these individuals are considered to consume low levels of food forms. Furthermore, severe periodontitis, stumps of teeth, dry mouth, and salivary hypofunction may interfere with oral intake and promote weight loss. Participants with problems identified during the oral examination were asked to report them to the facility staff. However, we have not received any reports on these issues. We believe that such problems did not arise in our study population because the included facilities were affiliated with members of the Geriatric Dentistry Society. Second, we focused on the food forms. However, experts in swallowing disorders have not determined the food forms of residents using detailed tests, such as video fluoroscopy or video endoscopy[91,92]. Third, since this was a cross-sectional study, we were unable to determine a causal relationship between denture use and food form. More research is needed to investigate this causal relationship.

5. Conclusion

In conclusion, the use of dentures was associated with food forms, even in LTCF residents with a severe decline in ADL and cognitive function. This highlights the importance of providing prosthodontic treatment to the elderly in need of long-term care and supporting the use of dentures in cooperation with caregivers if the elderly in need of long-term care are willing to use dentures.

Ethics Committee Approval

This study was approved by the ethics committee of the Japanese Society of Gerodontology (approval number: 2018-1) and the epidemiological research ethics committee of Hokkaido University (approval number: 2020-4) and was conducted following the ethical principles of the Declaration of Helsinki.

Informed Consent

Written informed consent forms were obtained from 888 residents and their families, and a survey was conducted between October 2018 and February 2019.

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COI declaration

The authors declare that there is no conflict of interest.

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