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ABSTRACT

The loss of teeth is known to influence the mastication of foods and nutritional status. Therefore, we hypothesize that poor dentition status can impair the systemic health of the aged. To clarify the influence of dentition status on deterioration in physical ability, mental impairment, and mortality, we conducted a six-year prospective cohort study of the institutionalized elderly living in 29 of the 30 institutions for the elderly in Kitakyushu, Japan. Bivariate analysis revealed that worse dentition status at baseline led to significantly worse physical and mental impairment, and higher mortality. In a multiple logistic regression analysis, the physical ability of edentulous subjects without dentures significantly deteriorated compared with that of dentate subjects with 20 or more teeth. The six-year mortality rate of the edentulous subjects without dentures was significantly higher than that of the subjects with 20 or more teeth. Poorer dentition status, especially edentulousness without dentures, may therefore be related to deterioration in the systemic health of the aged.

KEY WORDS: institutionalized elderly, cohort study, dentition status, physical and mental health status, mortality.

Influence of Dentition Status on Physical Disability, Mental Impairment, and Mortality in Institutionalized Elderly People

INTRODUCTION

The elderly population is increasing rapidly in many developed countries, and the increase constitutes a serious problem. The average life span in Japan has been the longest in the world for females since 1985, and for males since 1995. Moreover, it is estimated that the proportion of elderly people in the total population of Japan will surpass that of Sweden and be the highest in the world in 2000.

Many people usually lose many teeth with age. The loss of teeth reduces masticatory capacity (Carlsson, 1984; Leake, 1990) and subsequently influences the selection of foods and nutritional status (Wayler and Chauncey, 1983; Chauncey *et al.*, 1984). People who have lost many teeth often use dentures to support the impaired masticatory function. The adequate rehabilitation of edentulousness by the wearing of dentures has a beneficial effect on mastication (Gunne, 1985; Gunne and Wall, 1985) and diet (Elmståhl *et al.*, 1988; Ranta *et al.*, 1988).

In Japan, many elderly people who have lost many teeth do not use dentures, in spite of coverage by a public health insurance system for the aged (Miyazaki *et al.*, 1992). Poorer dentition status may have negative effects on systemic health and mortality through impaired masticatory function and malnutrition. To clarify these effects, we planned a community-based large-scale cohort study. Kitakyushu City has a population of one million, which includes about 2400 elderly residents of institutions. In this six-year follow-up study, approximately 80% of the institutionalized elderly were examined. We analyzed how dentition status, especially the number of teeth and use of dentures, influenced the subjects' general health, including mobility, dementia, and mortality.

MATERIALS & METHODS

Subjects

Kitakyushu City, Japan, has a total population of approximately one million, and the subjects in this study represent approximately 2% of the estimated total number of senior citizens (65 years or older) in Kitakyushu City. Between October, 1988, and February, 1989, baseline examinations and interviews were performed on 1929 (87%) of the 2220 residents in 29 of the 30 institutions for the elderly in Kitakyushu City (Miyazaki *et al.*, 1992). During the examination, the subjects' rights were protected, and informed consent was obtained from each study participant or his/her relatives. There were three types of institutions, classified according to the care requirements of their residents: special nursing homes (for elderly people who require a great deal of special care), nursing homes (for elderly people who require partial care), and homes for the aged (for elderly people who require little care). The aged with severe illnesses, such as cancer and acute diseases, do not stay in these institutions. The mean (\pm SD) age of the subjects was 79.7 (\pm 7.5) years (range: 59 to

107) at baseline. Six years later, from October, 1994, to March, 1995, a follow-up survey was carried out on the same subjects. At follow-up, complete clinical and interview data were collected from 719 of the original 1929 subjects. During the six-year period, 856 subjects had died and 187 subjects were hospitalized. The whereabouts of 167 subjects was unknown at the time of the follow-up examination.

Dentition Status

The dentition status of each subject was examined under sufficient artificial light, with dental mirrors and explorers, by two dentists trained in the use of epidemiological indices for oral health (Miyazaki *et al.*, 1992). Retained roots were excluded from the number of teeth. The use of dentures was defined by whether the subjects used dentures when they ate. Baseline dental status was divided into five categories, according to the number of teeth and the use of dentures: 20 or more teeth, 1 to 19 teeth using dentures, 1 to 19 teeth not using dentures, edentulous using dentures, and edentulous not using dentures. The absence of opposing pairs of natural posterior teeth is reportedly the most important factor influencing an individual's masticatory ability (Leake, 1990). All the subjects with 20 or more teeth were assumed able to masticate adequately with their own teeth because they had at least one posterior occlusal unit.

Systemic Health Status

Information about physical and mental health status and the systemic diseases affecting each person was obtained from the medical records of each institution. Only five subjects had anamneses of cancer, and no subjects were diagnosed with cancer at baseline. The subjects' physical and mental health status was checked and recorded by nurses belonging to each institution (Miyazaki *et al.*, 1992). The subjects' physical health status was classified into three categories according to their physical ability to move: good, able to walk unaided; fair, needs help to walk; and poor, bedridden. Mental health status was classified into three categories according to each subject's symptoms of dementia and degree of cognition: good, no symptoms of dementia or cognitive disability; fair, mild symptoms of dementia or cognitive disability; and poor, severe symptoms of dementia or cognitive disability. Since the baseline physical and mental health status were closely related ($r = 0.58, p < 0.001$), we had to refrain from putting these two variables into one formula. In analyses of mortality, which should consider an individual's physical and mental health status, the category with the worst score was used, as described previously (Miyazaki *et al.*, 1992). This variable was defined as "physical-mental health status": good, able to walk unaided and no symptoms of dementia or cognitive disability; fair, needs help to walk or mild symptoms of dementia or cognitive disability; and poor, bedridden or severe symptoms of dementia or cognitive disability. Six years later, the physical and

mental health status of the subjects was investigated by means of the same criteria used at baseline.

Outcome Variables

The subjects who were able to walk unaided at baseline, but became bedridden or needed help to move during the intervening 6 years, were

Table 1. Comparison of Baseline Characteristics of the Subjects

Variables	No. of Subjects (%)			
	Re-examined	Death	Hospitalization	Unknown
Dentition status				
≥ 20 teeth	76 (10.6)	41 (4.8) ^c	12 (6.4)	21 (12.6) ^b
1-19 teeth using dentures	174 (24.2)	147 (17.2)	56 (29.9)	63 (37.7)
1-19 teeth not using dentures	126 (17.5)	191 (22.3)	30 (16.0)	24 (14.4)
Edentulous using dentures	255 (35.5)	266 (31.1)	54 (28.9)	46 (27.5)
Edentulous not using dentures	88 (12.2)	211 (24.6)	35 (18.7)	13 (7.8)
Age				
59-69	93 (12.9)	51 (6.0) ^c	16 (8.6)	20 (12.0)
70-79	319 (44.4)	251 (29.3)	87 (46.5)	80 (47.9)
80-89	267 (37.1)	432 (50.5)	75 (40.1)	62 (37.1)
≥ 90	40 (5.6)	122 (14.3)	9 (4.8)	5 (3.0)
Sex				
Female	550 (76.5)	584 (68.2) ^c	141 (75.4)	118 (70.7)
Male	169 (23.5)	272 (31.8)	46 (24.6)	49 (29.3)
Physical health status				
Good	483 (67.2)	288 (33.6) ^c	102 (54.5) ^c	127 (76.0) ^a
Fair	203 (28.2)	371 (43.3)	50 (26.7)	35 (21.0)
Poor	33 (4.6)	197 (23.0)	35 (18.7)	5 (3.0)
Mental health status				
Good	517 (71.9)	350 (40.9) ^c	105 (56.1) ^c	140 (83.8) ^b
Fair	141 (19.6)	323 (37.7)	42 (22.5)	16 (9.6)
Poor	61 (8.5)	183 (21.4)	40 (21.4)	11 (6.6)
Classification of institution				
Home for the aged	131 (18.2)	60 (7.0) ^c	33 (17.6)	85 (50.9) ^a
Nursing home	203 (28.2)	126 (14.7)	45 (24.1)	47 (28.1)
Special nursing home	385 (53.5)	670 (78.3)	109 (58.3)	35 (21.0)
Cerebrovascular disorder				
Yes	143 (19.9)	251 (29.3) ^c	54 (28.9) ^b	25 (15.0)
No	576 (80.1)	605 (70.7)	133 (71.1)	142 (85.0)
Cardiovascular disease				
Yes	79 (11.0)	147 (17.2) ^c	25 (13.4)	14 (8.4)
No	640 (89.0)	709 (82.8)	162 (86.6)	153 (91.6)
Hypertension				
Yes	88 (12.2)	122 (14.3)	31 (16.6)	24 (14.4)
No	631 (87.7)	734 (85.7)	156 (83.4)	143 (85.6)
Respiratory disease				
Yes	28 (3.9)	48 (5.6)	11 (5.9)	7 (4.2)
No	691 (96.1)	808 (94.4)	176 (94.1)	160 (95.8)
Renal and urinary disease				
Yes	18 (2.5)	17 (2.0)	2 (1.1)	3 (1.8)
No	701 (97.5)	839 (98.0)	185 (98.9)	164 (98.2)
Gastrointestinal disease				
Yes	42 (5.8)	46 (5.4)	8 (4.3)	10 (6.0)
No	677 (94.2)	810 (94.6)	179 (95.7)	157 (94.0)
Musculo-skeletal disease				
Yes	115 (16.0)	91 (10.6) ^c	26 (13.9)	26 (15.6)
No	604 (84.0)	765 (89.4)	161 (86.1)	141 (84.4)
Cancer				
Yes	2 (0.3)	3 (0.4)	0 (0.0)	0 (0.0)
No	717 (99.7)	853 (99.6)	187 (100)	167 (100)

Chi-square tests were used for statistical analysis.
^a p < 0.05 compared with re-examined subjects.
^b p < 0.01 compared with re-examined subjects.
^c p < 0.001 compared with re-examined subjects.

Table 2. Predictors for Six-year Incidence of Physical Disability in the Institutionalized Elderly

Variables	No. of Subjects		Crude OR (95% CI)	Multivariate OR (95% CI)
	No Change	Physical Disability		
Dentition status				
≥ 20 teeth	51	8	1.0	1.0
1-19 teeth using dentures	106	31	1.9 (0.8-4.3)	1.2 (0.5-3.2)
1-19 teeth not using dentures	44	25	3.6 (1.5-8.8) ^b	1.3 (0.5-3.6)
Edentulous using dentures	109	74	4.3 (1.9-9.6) ^c	2.0 (0.8-5.1)
Edentulous not using dentures	11	24	13.9 (5.0-39.0) ^c	6.0 (1.9-19.3) ^b
Age				
59-69	56	13	1.0	1.0
70-79	169	55	1.4 (0.7-2.8)	1.1 (0.5-2.4)
80-89	92	74	3.5 (1.8-6.8) ^c	2.3 (1.1-5.1) ^a
≥ 90	4	20	21.5 (6.3-73.8) ^c	6.5 (1.7-25.9) ^b
Mental health status				
Good	292	120	1.0	1.0
Fair	24	30	3.0 (1.7-5.4) ^c	1.5 (0.8-2.9)
Poor	5	12	5.8 (2.0-16.9) ^b	2.7 (0.9-8.5)
Classification of institution				
Home for the aged	127	4	1.0	1.0
Nursing home	125	58	14.7 (5.2-41.8) ^c	12.6 (4.3-37.0) ^c
Special nursing home	69	100	46.0 (16.2-130.4) ^c	31.4 (10.6-93.0) ^c

Logistic regression analyses were performed on the 483 subjects who were able to walk unaided at baseline.

^a $p < 0.05$.

^b $p < 0.01$.

^c $p < 0.001$.

Table 3. Predictors for Six-year Incidence of Mental Impairment in the Institutionalized Elderly

Variables	No. of Subjects		Crude OR (95% CI)	Multivariate OR (95% CI)
	No Change	Mental Impairment		
Dentition status				
≥ 20 teeth	59	9	1.0	1.0
1-19 teeth using dentures	105	37	2.3 (1.0-5.1) ^a	1.9 (0.8-4.6)
1-19 teeth not using dentures	39	26	4.4 (1.9-10.3) ^c	2.3 (0.9-5.8)
Edentulous using dentures	134	65	3.2 (1.5-6.8) ^b	1.7 (0.7-4.0)
Edentulous not using dentures	24	19	5.2 (2.0-13.1) ^c	2.4 (0.9-6.5)
Age				
59-69	61	12	1.0	1.0
70-79	182	56	1.6 (0.8-3.1)	1.6 (0.8-3.4)
80-89	106	79	3.8 (1.9-7.5) ^c	3.5 (1.6-7.2) ^b
≥ 90	12	9	3.8 (1.3-11.0) ^a	2.7 (0.9-8.6)
Physical health status				
Good	309	103	1.0	1.0
Fair	49	48	2.9 (1.9-4.6) ^c	1.7 (1.0-2.8)
Poor	3	5	5.0 (1.2-21.3) ^a	3.3 (0.6-18.0)
Classification of institution				
Home for the aged	125	5	1.0	1.0
Nursing home	116	60	12.9 (5.0-33.3) ^c	10.5 (4.0-27.5) ^c
Special nursing home	120	91	18.9 (7.5-48.3) ^c	9.8 (3.6-26.5) ^c
Cerebrovascular disorder				
No	323	118	1.0	1.0
Yes	38	38	2.7 (1.7-4.5) ^c	1.9 (1.1-3.3) ^a

Logistic regression analyses were performed on the 517 subjects who had no mental impairment at baseline.

^a $p < 0.05$.

^b $p < 0.01$.

^c $p < 0.001$.

defined as having deterioration in physical health. The subjects who had no symptoms of dementia and cognitive disability at baseline, but had some symptoms of dementia or cognitive disability at follow-up, were defined as having deterioration in mental health. Information on death was obtained from the medical records of each institution, or in some cases from interviews with the subjects' relatives. "Unknown" subjects were excluded from the analysis of mortality.

Statistical Analysis

Statistical analysis was performed with SPSS (Version 6.1, SPSS Japan Inc., Tokyo, Japan). The *chi-square* test was used to examine differences in the baseline characteristics between the "re-examined" group and the other groups at follow-up. In the bivariate analysis, logistic regression analysis was used to analyze the factors associated with six-year physical disability, mental impairment, and mortality. The multivariate analysis included only the variables that were statistically significant ($p < 0.05$) in the bivariate analysis, and the odds ratios (OR) and 95% confidence intervals (CI) for each variable were calculated.

RESULTS

Table 1 shows the baseline characteristics of the subjects. Deceased subjects were older, and the proportion of males who died was higher than that of females. In addition, the deceased subjects had worse dentition and physical and mental health status at baseline than the re-examined subjects. Hospitalized subjects had worse physical and mental health status than the re-examined subjects. The oral and general health status of unknown subjects at baseline was better than that of re-examined subjects. Seventy percent of the subjects who had died were residents of special nursing homes, while half of the unknown subjects stayed in homes for the aged at baseline. Baseline dentition status of the subjects was different in each type of institution. The numbers of the edentulous subjects in special nursing homes, nursing homes, and homes for the aged were 642 (55.2%), 186 (49.7%), and 81 (36.2%), respectively, and the numbers of the edentulous subjects not using dentures were 292 (25.1%), 36 (9.6%), and 6 (2.7%), respectively.

At follow-up, we examined the incidence of physical disability in the subjects who were able to walk unaided at baseline. In the six-year period, 162 of the 483 subjects who could walk unaided at baseline became bedridden or needed help to walk (Table 2). The incidence of physical disability was greater in the categories of subjects with fewer teeth. The incidence was also greater in the subjects not using dentures within the same teeth category. Dentition status, age, mental health status, and classification of institution were significant risk factors for the incidence of physical disability in the bivariate analyses. In the multivariate

model, dentition status, age, and classification of institution had significant relationships to the incidence of physical disability. The OR for the physical disability of edentulous subjects not using dentures to the subjects with 20 or more teeth was quite high (OR = 6.0, 95% CI = 1.9-19.3).

Concerning the incidence of mental impairment in the follow-up period, 156 of the 517 subjects who had no symptoms of dementia or cognitive disability at baseline developed some dementia or cognitive disability during the six-year period (Table 3). In the bivariate analyses, the probability of the development of mental impairment over the six-year period was higher in subjects who were older, had worse dentition and physical health status, stayed in an institution giving more care, or had a cerebrovascular disorder. In both the fewer teeth and edentulous categories, the incidence of mental impairment was greater in the subjects not using dentures than in those using dentures, but it was not significant after multivariate adjustment.

At the time of the follow-up survey, there were 856 known deaths. Table 4 shows the correlation between six-year mortality and several factors measured at baseline. During the six-year period, 63% of edentulous subjects not using dentures at baseline died, while only 32% of the subjects who had 20 or more teeth at baseline died. The risk of death was significantly associated with worse dentition and physical-mental health status, older age, male sex, type of institution, cerebrovascular disorder, cardiovascular disease, and musculo-skeletal disease in the bivariate analyses. In the multiple logistic regression model, dentition status, age, sex, physical-mental health status, cardiovascular disease, and musculo-skeletal disease were shown to be significant risk factors of high mortality. Edentulous subjects not using dentures were significantly associated with six-year mortality, independent of age and other variables (OR = 1.8, 95% CI = 1.1-2.8).

DISCUSSION

In this study, the bivariate analysis identified significant risks for physical disability, mental impairment, and mortality in subjects with fewer teeth and not using dentures. Aging is considered to be the most important risk factor for physical disability in the elderly population (Hébert *et al.*, 1997; Jette and Branch, 1981), and it is also a risk factor for dementia (Aronson *et al.*, 1991; Amaducci and Tesco, 1994; Gao *et al.*, 1998). Therefore, the health disorders and high mortality seen in our subjects could be a result of aging. The edentulous subjects not using dentures were found more in special nursing homes than in the other two types of institutions. The possibility exists that those may have already been suffering from a higher degree of physical and mental impairment. However, after adjustment

Table 4. Predictors for Six-year Mortality in the Institutionalized Elderly

Variables	No. of Subjects		Crude OR (95% CI)	Multivariate OR (95% CI)
	Survival	Death		
Dentition status				
≥ 20 teeth	88	41	1.0	1.0
1-19 teeth using dentures	230	147	1.4 (0.9-2.1)	1.3 (0.8-2.0)
1-19 teeth not using dentures	156	191	2.6 (1.7-4.0) ^c	1.5 (0.9-2.4)
Edentulous using dentures	309	266	1.8 (1.2-2.8) ^b	1.3 (0.8-2.4)
Edentulous not using dentures	123	211	3.7 (2.4-5.7) ^c	1.8 (1.1-2.8) ^a
Age				
59-69	109	51	1.0	1.0
70-79	406	251	1.3 (0.9-1.9)	1.4 (0.9-2.0)
80-89	342	432	2.7 (1.9-3.9) ^c	2.8 (1.8-4.1) ^c
≥ 90	49	122	5.3 (3.3-8.5) ^c	4.5 (2.7-7.5) ^c
Sex				
Female	691	584	1.0	1.0
Male	215	272	1.5 (1.2-1.9) ^c	2.2 (1.7-2.7) ^c
Physical-mental health status				
Good	498	225	1.0	1.0
Fair	275	352	2.8 (2.3-3.5) ^c	2.4 (1.8-3.2) ^c
Poor	133	279	4.6 (3.6-6.0) ^c	3.6 (2.6-5.1) ^c
Classification of institution				
Home for the aged	164	60	1.0	1.0
Nursing home	248	126	1.4 (1.0-2.0)	0.9 (0.6-1.4)
Special nursing home	494	670	3.7 (2.7-5.1) ^c	1.3 (0.9-2.0)
Cerebrovascular disorder				
No	709	605	1.0	1.0
Yes	197	251	1.5 (1.2-1.9) ^c	0.9 (0.7-1.1)
Cardiovascular disease				
No	802	709	1.0	1.0
Yes	104	147	1.6 (1.2-2.1) ^c	1.6 (1.2-2.1) ^b
Musculo-skeletal disease				
No	765	765	1.0	1.0
Yes	141	91	0.6 (0.5-0.9) ^b	0.6 (0.5-0.9) ^b

Logistic regression analyses were performed on the 1762 subjects.

^a p < 0.05.

^b p < 0.01.

^c p < 0.001.

for age, classification of institution, and other variables, the edentulous aged not using dentures had a significant risk for physical disability and mortality.

The loss of many teeth is known to decrease occlusal force, especially in the edentulous (van der Bilt *et al.*, 1993). The decline in occlusal function resulting from tooth loss causes problems with chewing, swallowing, and food selection (Ship *et al.*, 1996), and the nutritional status of edentulous people deteriorates (Joshi *et al.*, 1996). It is reported that malnutrition in the elderly increases their morbidity and mortality (Sullivan *et al.*, 1990). Therefore, difficulty in maintaining a nutritious diet may cause the increased incidence of physical disability and mortality in edentulous people without dentures.

A previous case-control study suggested that loss of teeth is one of the risk factors for Alzheimer's disease (Kondo *et al.*, 1994). An animal experiment with aged rats showed that spatial memory and the cholinergic neuronal system are impaired by the loss of molar teeth, suggesting that tooth loss is one of the risk factors for dementia (Kato *et al.*, 1997). In

our longitudinal study, however, the relationship between baseline dentition status and follow-up mental impairment was not significant. Since the classification of mental health status used in this study consisted of only 3 categories, a more detailed classification, or more subjects, may be needed to clarify such a relationship.

A few reports have suggested that mortality is higher in elderly people with fewer teeth than in elderly people with many teeth (Österberg *et al.*, 1990; Appollonio *et al.*, 1997). In this study, those with the worst dentition status (edentulous subjects without dentures) had a significant risk for death independent of physical-mental health status at baseline. Physical disability of the aged is also known to lead to high mortality (Jagger and Clarke, 1988; Tsuji *et al.*, 1994). In our study, increased mortality was observed in the subjects with worse physical-mental health status at baseline. Since the edentulous without dentures had a significant risk of physical disability, physical health disorders derived from worse dentition status might lead to death in edentulous subjects.

Several previous studies reported that low income might affect mortality (Anderson *et al.*, 1997; Lantz *et al.*, 1998). In our study, the six-year mortality of edentulous subjects without dentures was significantly high. It is possible to ascribe the incidence of mortality in the subjects without dentures to difficulty in receiving medical treatment encountered by people with low incomes. In Japan, however, there is a public medical insurance system. This system provides medical and dental treatment at low cost for most Japanese people whether rich or poor. Furthermore, medical and dental treatment for Japanese over 65 years old is a social benefit provided without periodic premium. Indeed, Uchida *et al.* (1992) reported that low income did not shorten the life expectancy of elderly Japanese males, and it lengthened that of elderly Japanese females. A more expensive lifestyle might accelerate the risk of chronic adult disease. Uchida *et al.* (1992) showed that the urbanization factor, including educational level, does not affect life expectancy for the aged in Japan, although the factor affects the life expectancy of the younger generation. Moreover, the educational level of the Japanese elderly was reported not to affect mortality (Haga *et al.*, 1991), although several studies showed a relationship between education and life expectancy in the elderly in Western countries (Snowdon *et al.*, 1989; Guralnik *et al.*, 1993). Factors such as income and educational level might not affect mortality in our study.

The rapid recent increase in the aged population is a serious problem in Japan. The number of people older than age 65 exceeds 16.8% of the Japanese population (SBSC, 2000), and the numbers are increasing more rapidly than in any other country. Therefore, the proportion of elderly people suffering from physical handicaps or dementia will increase. According to our baseline data, about 50% of the subjects were edentulous and about 35% of the edentulous subjects did not use dentures. Our study suggests that the edentulous elderly who do not use dentures are at significant risk of physical disability and mortality in the future. Maintaining many teeth or using dentures after losing many teeth may be important for the health of the elderly. More functional occlusion may lead to a longer life expectancy.

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