edentulism [18] or periodontitis [19]. There are 2 plausible relationship mechanisms between social participation and dental health: social network as a main effect, and stress buffering [20]. The main effect of social participation is obtained from social relationships, and this mechanism is beneficial regardless of whether individuals are under stress. Participation in a broad range of social relationships develops a person's social network. Individuals in a social network are subject to social controls and peer pressure that influence normative dental health behaviors (e.g., developing good dental habits and quitting smoking). For example, the cessation of smoking in one person appears to be highly related to the smoking behavior of others nearby in that person's social network [21]. Social network ties also provide multiple sources of information that could influence behaviors relevant to oral health, result in the effective use of available dental health services, or help people avoid stressful or other high-risk situations. In addition to this main effect, stress buffering is also considered a pathway to good dental health. A systematic review of the literature suggests that psychological stress causes periodontal disease, which is a key risk factor for tooth loss [22]. Social networks are a source of social support, which in turn provides psychological and material resources intended to benefit an individual's ability to cope with stress. As social support promotes less threatening interpretations of adverse events and effective coping strategies, it can shield individuals from the effects of stressful experiences. This mechanism is called stress buffering.

Despite a recent increase in studies on social participation and health, only a small number of studies have focused on the association between social participation and oral health. In addition, previous oral epidemiological studies have defined social participation as only belonging or not belonging to social relationships, or as high or low frequency of social engagement. A meta-analysis revealed that definitions of social participation mostly focused on questions of who, how, what, with whom, and where [6]. To our knowledge, the present study is the first to focus on the number, type, and frequency of social activities. This study aimed to quantify the associations between social participation and dental health status in community-dwelling older Japanese adults.

Methods

Study sample

The present analysis was based on a subset of the Japan Gerontological Evaluation Study (JAGES) project data. The JAGES project is an ongoing prospective cohort study investigating factors associated with the loss of health related to functional decline or cognitive impairment among individuals aged 65 years or older. In 2010, self-administered postal questionnaires were distributed to all people aged ≥65 years in Iwanuma City, Miyagi Prefecture, Japan (n = 8,576), and 5,058 (response rate, 59.0%) people returned the questionnaires. After excluding respondents who failed to provide information on sex, dental health status, or social participation, the data from 3,517 respondents were analyzed. If the respondents did not respond to the other variables, the corresponding observations were assigned to "missing" categories. Ethical approval for the study was obtained from the Ethics Committee at Tohoku University and Nihon Fukushi University.

Outcome variable

The number of remaining natural teeth, derived from responses collected through the self-administered questionnaire, was used as an indicator of dental health status. Respondents were asked to classify their dental health status into one of 4 categories: ≥20 teeth remaining, 10–19 teeth remaining, 1–9 teeth remaining, or no teeth remaining.

Main predictors

Social participation was defined as the person's involvement in social activities. First, respondents were asked whether they belonged to political organizations or associations, industrial or professional groups, volunteer groups, senior citizens' clubs, religious groups or associations, sports groups, neighborhood community associations, or hobby clubs. Second, respondents were asked to indicate the frequency of participation in each group: 2–3 times per week, once per week, several times per month, several times per year, or almost never. As there were very few "2–3 times per week" responses for 6 groups (political organizations or associations, industrial or professional groups, volunteer groups, senior citizens' clubs, religious groups or associations, and neighborhood community associations), we re-categorized these social participation variables: once or more per week, several times per month, several times per year, almost never. As our study also focused on the number of social activities, we calculated the numbers of social activities and created 6 categories: 0 groups, 1 group, 2 groups, 3 groups, 4 groups, and ≥5 groups.

Covariates

It was assumed that physical health status was associated with both social participation and dental health status. Activity of daily living and current medical history were used as indicators of physical health status. Activity of daily living was categorized as independent, partially dependent, and dependent. Current medical history was measured by the question, "Do you receive treatment now?" to which respondents answered "yes" or "no." Sex, age, and marital status were used as socio-demographic characteristics. Age groups were categorized as 65–69, 70–74, 75–79, 80–84, and ≥85 years. Marital status was categorized as married, widowed, separated, never married, and other. Educational attainment and annual equivalent income were used as indicators of socioeconomic status. Educational attainment was categorized as <6, 6–9, 10–12, and ≥13 years. Annual equivalent income was divided into quartiles: lowest, low-middle, high-middle, and highest.

Statistical analysis

Descriptive statistics were used to characterize the respondents. We performed ordinal logistic regressions to examine the associations between social participation and dental health status. We calculated the odds ratios (OR) and 95% confidence intervals (95% CI) for an increase in the remaining teeth category based on the number, type, and frequency of social activities. To estimate the overall effect of social participation, we used a dichotomized variable of social participation (1 = participating in ≥1 groups, 0 = not participating in any group). Variables on social participation were included separately in the different models. In the univariate model (Model 1), we calculated the crude OR for dental health status based on the number of social activities and the type and frequency of social participation. In the multivariable model (Model 2), we added all covariates into the univariate model. In order to assess the public health impact of social participation, we calculated the population-attributable fraction (PAF) of having ≥20 teeth to social participation. The PAF is generally defined as the reduction in the burden of disease (or risk factor) that would be achieved if the population had been entirely unexposed, compared with its current exposure pattern [23]. In this study, we treated the PAF as the increase in the number of people with ≥20 remaining

teeth that would be achieved if the entire population participated in some kind of social group, compared with its current participation pattern. We calculated a PAF for ≥20 remaining teeth because the retention of a minimum of 20 functional natural teeth at the age of ≥65 years is a goal for oral health specified by the WHO/*Federation Dentaire Internationale* in 2000 [24]. The goal for an acceptable level of oral health determined by the Japan Dental Association is the retention of at least 20 functional teeth until the age of 80 years (8020 movement). A previous study also indicated that among older people, those with ≥20 teeth had higher food intakes than those with ≤19 teeth [25]. All analyses were performed using SPSS statistical software (version 17.0, SPSS, Chicago, IL).

Results

The demographic and health characteristics of all respondents (n = 3,517; average age, 73.5 years for men and 75.0 years for women) in the study are shown in Tables 1 and 2. Of the respondents, 34.2% reported having ≥20 teeth, 27.1% reported having 10–19 teeth, 26.3% reported having 1–9 teeth, and 12.4% reported having no teeth. Of the respondents, 13.9% belonged to political organizations or associations, 15.2% to industrial or professional groups, 16.4% to volunteer groups, 15.7% to senior citizens' clubs, 7.3% to religious groups or associations, 24.5% to sports groups, 46.8% to neighborhood community associations, and 41.1% to hobby clubs.

Of all respondents, 69.6% participated in ≥1 groups, and 30.4% did not participate in any group. Compared to the non-participants, participants had significantly higher odds of having a greater number of teeth (OR = 2.40, 95% CI = 2.10–2.74). After adjusting for sex, age, marital status, current medical history, activity of daily living, educational attainment, and annual equivalent income, social participation appeared to be related with an increased likelihood of having a greater number of teeth in old age (OR = 1.30, 95% CI = 1.10–1.53).

Table 3 illustrates the association between dental health status and the number of social activities. Participating in ≥1 groups was significantly associated with odds of having more remaining teeth that were more than twice as high as compared with non-participation (Model 1). After adjusting for all covariates, participating in 4 groups was associated with significantly higher odds (OR = 1.46, 95% CI = 1.11–1.93) of having more remaining teeth compared with non-participation (Model 2). Table 4 shows the association between dental health status and the type and frequency of social participation. The groups significantly associated with a higher number of remaining teeth were industrial or professional groups, volunteer groups, sports groups, neighborhood community associations, and hobby clubs (Model 1). After adjusting for all covariates, participating in sports groups (2–3 times per week, OR = 1.31, 95% CI = 1.01–1.69), neighborhood community associations (several times per year, OR = 1.19, 95% CI = 1.02–1.39), or hobby clubs (2–3 times per week, OR = 1.36, 95% CI = 1.05–1.76; once per week, OR = 1.39, 95% CI = 1.10–1.75; several times per year, OR = 1.41, 95% CI = 1.11–1.81) was significantly associated with having more teeth (Model 2). With the exception of these 3 groups, although most types of participation were associated with higher odds of having more teeth, the associations were explained by covariates. This indicates that healthier people tend to have more teeth and participate in groups.

The PAFs, or the contribution of social participation to having ≥20 teeth, are shown in Tables 3 and 4. The PAFs for the number of social activities and 3 types of social participation variables that were significantly associated with dental health (i.e., sports groups, neighborhood community associations, and hobby clubs) were 7.5%–31.6%. The largest PAF (31.6%) was for participation in ≥1 social groups.

Table 1. Characteristics of respondents.

	n	%		n	%
Sex			**Educational attainment (years)**		
Men	1,681	47.8	<6	86	2.4
Women	1,836	52.2	6–9	1,071	30.5
Age (years)			10–12	1,521	43.2
65–69	1,147	32.6	≥13	762	21.7
70–74	950	27.0	Missing	77	2.2
75–79	649	18.5	**Annual equivalent income (quartiles)**		
80–84	418	11.9	Lowest	718	20.4
≥85	346	9.8	Low-middle	731	20.8
Missing	7	0.2	High-middle	801	22.8
Marital status			Highest	792	22.5
Married	2,416	68.7	Missing	475	13.5
Widowed	855	24.3	**Number of remaining natural teeth**		
Separated	111	3.2	≥20	1,203	34.2
Never married	50	1.4	10–19	952	27.1
Other	28	0.8	1–9	925	26.3
Missing	57	1.6	No	437	12.4
Current medical history			**Number of social activities (groups)**		
Yes	2,741	77.9	0	1,068	30.4
No	731	20.8	1	749	21.3
Missing	45	1.3	2	644	18.3
Activity of daily living			3	456	13.0
Independent	3,155	89.7	4	281	8.0
Partially dependent	208	5.9	≥5	319	9.1
Dependent	122	3.5			
Missing	32	0.9			

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Discussion

Our study demonstrates a significant positive association between social participation and dental health status in a representative sample of men and women aged ≥65 years in a municipality in Japan. Among those with ≥20 remaining teeth, 31.6% of cases in the population might be attributed to participation in ≥1 social groups. To our knowledge, no published reports have examined the associations between dental health status and the number, type, and frequency of social activities. In relation to the type and frequency of social participation, frequent participation in sports groups, rare participation in neighborhood community associations, or participation in hobby clubs with little regard to frequency were significantly associated with dental health status, even after adjusting for demographic variables and social class indicators. In relation to the number of social activities, almost all amounts of social participation were significantly positively associated with dental health.

Our results may support the earlier-described mechanisms linking social participation and dental health status (i.e., social network as a main effect and stress buffering). There was a

Table 2. Characteristics of respondents according to type and frequency of social participation.

	2–3 times per week n (%)	Once per week n (%)	Several times per month n (%)	Several times per year n (%)	Almost never n (%)
Type and frequency of social participation					
Political organization or association	45 (1.3)	32 (0.9)	90 (2.6)	321 (9.1)	3,029 (86.1)
Industrial or professional group	56 (1.6)	36 (1.0)	126 (3.6)	318 (9.0)	2,981 (84.8)
Volunteer group	52 (1.5)	59 (1.7)	192 (5.5)	275 (7.8)	2,939 (83.6)
Senior citizens' club	27 (0.8)	61 (1.7)	185 (5.3)	280 (8.0)	2,964 (84.3)
Religious group or association	23 (0.7)	34 (1.0)	81 (2.3)	120 (3.4)	3,259 (92.7)
Sports group	259 (7.4)	245 (7.0)	183 (5.2)	176 (5.0)	2,654 (75.5)
Neighborhood community association	44 (1.3)	61 (1.7)	282 (8.0)	1,260 (35.8)	1,870 (53.2)
Hobby club	284 (8.1)	350 (10.0)	500 (14.2)	311 (8.8)	2,072 (58.9)

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significant association with better dental health status for participants in the groups with higher social participation rates. In groups with high participation rates that include many social ties, people may easily develop social networks and receive social support.

In addition to these positive effects of social participation on health, social participation can have negative effects on health. Social networks provide opportunities for conflict, exploitation, stress transmission, misguided attempts to help, and feelings of loss and loneliness [20]. These potentially negative aspects of social networks can cause psychological stress, which in turn adversely affects dental health. The results of this study showed no significant association between frequent participation in neighborhood community associations and dental health, but there was a significant association between relatively rare participation and dental health. The negative effects of social participation on health may be a reason for this. Participation in neighborhood community associations might include obligatory activities characterized by the negative aspects of social networks. People who frequently participate in obligatory activities may experience stress, leading to oral disease. Therefore, frequent participation in neighborhood community associations might not be significantly associated with having more teeth. Similarly, where participation in $\geq$5 groups is concerned, social participation might not be significantly associated with having more teeth for an increase in the type of social participation that has negative effects on health.

Our findings are generally consistent with those of previous studies indicating that participating in social activities benefits dental health status among middle-aged and older people. Rodrigues et al. suggested that social participation is significantly associated with a lower prevalence of edentulism among older adults [18]. Merchant et al. also suggested that men who participate in religious meetings are associated with a reduced risk of developing periodontitis [19].

To our knowledge, no study has specifically examined the differences between men and women in relation to the association between social participation and dental health status, though previous work has indicated that such differences exist. Among women, participation in social networks may increase levels of psychological stress [26]. In our study, 75.3% of men participated in $\geq$1 groups compared to 64.5% of women. However, with respect to the main results, we found few differences between men and women.

The results of this study have public health implications. Our goal was to estimate the PAF associated with participation in social activities (compared to non-participation) for having $\geq$20 remaining teeth. The largest PAF (31.6%) was for participation in $\geq$1 social groups, which implies that in 31.6% of cases in the population, presence of $\geq$20 remaining teeth may be attributed to

Table 3. Association of dental health status with number of social activities determined by ordinal logistic regression.

	Model 1	Model 2		
	Crude OR (95% CI)	Adjusted OR [a] (95% CI)	n of ≥20 teeth (%)	PAF [b] (%)
Number of social activities (groups)				31.6
0	1.00	1.00	250 (23.4)	
1	2.21 (1.86–2.62)	1.31 (1.07–1.59)	279 (37.2)	
2	2.22 (1.85–2.65)	1.21 (0.98–1.49)	231 (35.9)	
3	2.84 (2.32–3.48)	1.36 (1.07–1.72)	194 (42.5)	
4	2.90 (2.28–3.70)	1.46 (1.11–1.93)	125 (44.5)	
≥5	2.31 (1.84–2.90)	1.25 (0.96–1.62)	124 (38.9)	

OR = odds ratio; CI = confidence interval.
[a]Odds ratio adjusted for sex, age, marital status, current medical history, activity of daily living, educational attainment, and annual equivalent income.
[b]Population-attributable fraction.
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Table 4. Association of dental health status with type and frequency of social participation determined by ordinal logistic regression.

	Model 1	Model 2		
	Crude OR (95% CI)	**Adjusted OR[a] (95% CI)**	**n of ≥20 teeth (%)**	**PAF[b] (%)**
Type and frequency of social participation				
Political organization or association				1.4
Once or more per week	1.15 (0.77–1.74)	0.97 (0.61–1.53)	26 (33.8)	
Several times per month	1.33 (0.91–1.95)	1.06 (0.69–1.61)	35 (38.9)	
Several times per year	1.14 (0.93–1.41)	0.89 (0.70–1.11)	120 (37.4)	
Almost never	1.00	1.00	1,022 (33.7)	
Industrial or professional group				3.6
Once or more per week	1.29 (0.88–1.87)	1.03 (0.68–1.58)	33 (35.9)	
Several times per month	1.75 (1.26–2.44)	1.17 (0.82–1.67)	55 (43.7)	
Several times per year	1.51 (1.22–1.87)	1.05 (0.83–1.32)	132 (41.5)	
Almost never	1.00	1.00	983 (33.0)	
Volunteer group				4.3
Once or more per week	1.38 (0.98–1.96)	1.11 (0.76–1.61)	44 (39.6)	
Several times per month	1.85 (1.41–2.42)	1.31 (0.97–1.76)	89 (46.4)	
Several times per year	1.37 (1.10–1.72)	1.02 (0.79–1.31)	108 (39.3)	
Almost never	1.00	1.00	962 (32.7)	
Senior citizens' club				−1.7
Once or more per week	0.76 (0.52–1.12)	0.89 (0.58–1.36)	27 (30.7)	
Several times per month	0.77 (0.59–1.01)	0.76 (0.56–1.02)	58 (31.4)	
Several times per year	0.80 (0.65–1.00)	0.89 (0.70–1.14)	87 (31.1)	
Almost never	1.00	1.00	1,031 (34.8)	
Religious group or association				0.4
Once or more per week	0.99 (0.61–1.58)	0.87 (0.51–1.48)	18 (31.6)	
Several times per month	1.06 (0.71–1.58)	1.07 (0.68–1.68)	28 (34.6)	
Several times per year	1.34 (0.96–1.87)	1.31 (0.90–1.90)	47 (39.2)	
Almost never	1.00	1.00	1,110 (34.1)	
Sports group				7.5
2–3 times per week	1.90 (1.50–2.41)	1.31 (1.01–1.69)	115 (44.4)	
Once per week	1.73 (1.36–2.20)	1.20 (0.92–1.56)	104 (42.4)	
Several times per month	1.64 (1.25–2.16)	0.99 (0.74–1.34)	75 (41.0)	
Several times per year	1.54 (1.17–2.04)	1.02 (0.75–1.39)	69 (39.2)	
Almost never	1.00	1.00	840 (31.7)	
Neighborhood community association				14.5
Once or more per week	1.42 (0.99–2.02)	0.98 (0.65–1.47)	34 (32.4)	
Several times per month	1.63 (1.30–2.05)	0.93 (0.72–1.19)	100 (35.5)	
Several times per year	1.83 (1.60–2.08)	1.19 (1.02–1.39)	522 (41.4)	
Almost never	1.00	1.00	547 (29.3)	
Hobby club				16.8
2–3 times per week	1.98 (1.58–2.49)	1.36 (1.05–1.76)	122 (43.0)	
Once per week	2.06 (1.67–2.54)	1.39 (1.10–1.75)	157 (44.9)	
Several times per month	1.84 (1.54–2.20)	1.16 (0.95–1.42)	194 (38.8)	
Several times per year	2.13 (1.71–2.65)	1.41 (1.11–1.81)	140 (45.0)	
Almost never	1.00	1.00	590 (28.5)	

OR = odds ratio; CI = confidence interval.
[a]Odds ratio adjusted for sex, age, marital status, current medical history, activity of daily living, educational attainment, and annual equivalent income.
[b]Population-attributable fraction.
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participation in ≥1 social groups. Similarly, the PAFs for participation in sports groups, neighborhood community associations, and hobby groups were 7.5%, 14.5%, and 16.8%, respectively, for having ≥20 remaining teeth. Therefore, promoting and supporting opportunities for social participation, especially in sports groups, neighborhood community associations, or hobby clubs, as a public health intervention may contribute to an increase in the number of older people with ≥20 remaining teeth.

Our study has several limitations as well as strengths. First, the response rate was moderate (59.0%); hence, our results may have been affected by selection bias. Second, our research data were derived from self-reported questionnaires, raising issues of information bias regarding the true number of remaining teeth. However, self-reports have yielded reasonably valid estimates for the number of teeth in national epidemiological surveys in several prior studies [27,28]. In a study of 2,496 Japanese older people, the difference between the self-reported number of teeth and the clinically examined number of teeth was very small and insignificant according to the *t*-test, and the correlation between the 2 groups was very high (r = 0.93) [28]. Therefore, it is reasonable to assume that self-reported questionnaires can provide sufficiently reliable data about the number of remaining teeth. Third, our study was cross-sectional; therefore, it was not possible to generate any statements on causation. The present cross-sectional study could not exclude the possibility of reverse causation, in that people with good oral health tend to participate in social activities. Longitudinal studies or intervention studies are needed to examine the effects of social participation on dental health status. Lastly, our study participants were from one medium-sized municipality in Japan; hence, the generalizability of our results is limited. Caution should be exercised when interpreting our results, as it requires the somewhat strong assumption that the data we used for our analysis are generalizable to the entire population.

However, the population sample also could be considered a strength, as our data were less affected by geographic and cultural factors between municipalities, which provides some assurance of internal validity. The level of detail included in the social participation variable is another strength. Lastly, our data were reliable because all of the older residents in one city were recruited for our survey, and a large number of people participated.

Conclusion

Social participation was significantly and positively associated with better dental health status among older Japanese adults. Approximately one-third of the participants had ≥20 teeth, which may have been attributable to their participation in ≥1 social groups, though the present cross-sectional design could not exclude the possibility that people with good oral health tend to participate in social activities. In addition, our results indicate the possibility that participation in sports groups, neighborhood community associations, or hobby clubs in later life is protective of dental health beyond individual differences in demographic variables and social class indicators.

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Author Contributions

Conceived and designed the experiments: KT JA KK KO. Performed the experiments: KT KO. Analyzed the data: KT JA. Contributed reagents/materials/analysis tools: KT JA KO. Wrote the paper: KT JA KK.

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総　説

歯周病と脳血管疾患の関連
—歯周病測定指標の特性を考慮したメタアナリシス—

松山　祐輔[1)]　相田　潤[1)]　竹内　研時[2)]　伊藤　奏[1)]　中安美枝子[3)]
小山史穂子[1)]　長谷　晃広[1)]　坪谷　透[1)]　小坂　健[1)]

概要：2000年代より歯周病と循環器疾患の関連に関する報告が急増しているが，歯周病の評価指標は多様であり，病態評価は用いる指標に左右されるとの報告がなされている．このため，過去の研究における指標が統一されていないことは，研究結果に影響を及ぼしていると考えられる．過去に複数のメタアナリシスが実施されているが，歯周病の評価指標の違いは考慮されていない．そこで，本研究では，代表的な歯周病の測定指標を，a）測定時の炎症を反映する指標（歯肉出血の有無，歯周ポケットの深さの程度）とb）測定時の炎症に左右されない指標（アタッチメントレベル）に分け，歯周病と脳血管疾患の関連について，メタアナリシスにより検討した．

電子データベースによる検索により684本の文献を得，追加的な文献としてこれらの文献のうち2012年に出版されたレビューの引用から，新たに4本の文献を得た．合計688本の文献から，包含基準を満たす11本を解析に使用した．解析の結果，a）では歯周病と脳卒中の間に有意な関連は認められず（オッズ比=1.35，95%信頼区間；0.90-2.02），b）では歯周病患者は脳血管疾患が多いという，有意な正の関連を認めた（オッズ比=1.96，95%信頼区間；1.32-2.90）．

本研究から，アタッチメントレベルは，歯肉出血や歯周ポケットの深さの程度に比べ，脳血管疾患との間に強い関連をもつことが明らかになった．

索引用語：歯周病，歯周炎，歯肉炎，脳血管疾患，メタアナリシス

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緒　言

2000年代より歯周病と循環器疾患の関連に関する報告が急増しているが，両疾患の関係は，文献により異なっている[1-8]．関連はあるとする文献が多いものの，交絡等の問題から，因果関係についての一致した見解は得られていない．過去に行われた一次研究の例として，2003年にElterらが6,436名の米国の一般成人を対象に行った横断研究では，歯周病患者では有意に脳血管疾患罹患既往が多かった（Odds Ratio（OR）=1.30, 95% Confidence Interval（CI）；1.02-1.70）ことが報告されている[1)]．また，2004年にDörferらが95名の入院患者および地域住民を対象に行った症例対照研究では，CAL 3 mm以下の群に比べ，CAL 4.5～6 mm群とCAL 6 mm以上群は，脳血管疾患罹患既往が有意に多い（それぞれOR=4.82, 95%CI；1.13-8.13，OR=7.38，95%CI；1.55-15.03）ことが報告されている[2)]．一方，2001年にHowellらが22,037名の男性医師を対象としたコホート研究では，歯周病と脳卒中血管疾患発症の間に有意な関連はみられなかった（OR=1.01，95%CI；0.81-1.27）[3)]．このようななか，2012年にAmerican Heart Associationから出された473本の文献を用いたシステマティックレビューに基づいた声明では，歯周病と循環器疾患の間に，関連（association）は存在するものの，因果関係（causation）については更なる検討が必要である，とされている[7)]．

歯周病を評価する際に用いられる指標は，歯肉出血（Bleeding on Probing：BOP），歯周ポケット深さ（Probing Pocket Depth：PPD），アタッチメントレベル（Clinical Attachment Level：CAL）が代表的である[7)]が，その他にもレントゲン上の骨吸収状態，過去に歯科医師

[1)] 東北大学大学院歯学研究科口腔保健発育学講座国際歯科保健学分野
[2)] 九州大学大学院歯学研究院口腔予防医学分野
[3)] 浜松市北区健康づくり課

から受けた診断の有無，患者の主観的評価など，多岐に渡る．さらに，歯周病の病態評価は用いる指標に左右される[9]．そのため歯周病の疫学研究は測定指標や定義の多様性により複雑化していることが指摘されている[10]．各文献で歯周病の評価指標が一貫していないことは，歯周病と脳血管疾患の関連についての先行研究の結果に，少なからず影響を与えていると考えられる．これは，過去のメタアナリシスにおいて，異なる指標で測定された文献を統合したことが研究手法の限界として挙げられている点からも窺える[4]．しかし，これまで歯周病の評価指標の特性を考慮してメタアナリシスを行ったものは，筆者らが調べた限りでは存在しない．

脳血管疾患が日本の死因の第4位である[11]こと，また，歯周病が高い有病率である一方で，予防可能な疾患であることを考慮すると，両疾患の関連および因果性を明らかにすることの意義は大きいと考えられる．そこで本研究の目的は，代表的な歯周病の評価指標であるBOP，PPD，CALを，各特性に基づいて分類，評価指標によるばらつきを小さくしたうえで，各指標と脳血管疾患発症との関連を，メタアナリシスにより明らかにすることとした．

方　法

本研究における文献検索および一次研究の読み込みと質の評価は，一人の研究者によって行われた．

1. 文献検索

キーワードは#1："periodontitis"，#2："periodontal disease"，#3："tooth disease"，#4："stroke"，#5："brain ischemia"，#6："cerebrovascular disorder"，#7："brain disease"，#8："cerebral hemorrhage"，#9："cerebral ischemia"，#10："cerebrovascular disease"，#11："bleeding in the brain"，#12："brain bleeding"，#13："cerebral apoplexy"，#14："encephalorrhagia"，#15："hematencephalon"，#16："cerebrovascular accident"，#17：歯周疾患，#18：歯周病，#19：脳血管疾患，#20：脳血管障害，#21：脳出血，#22：脳梗塞とした．検索式は，PubMedおよびScopusにおいては，(#1 OR #2 OR #3) AND (#4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10 OR #11 OR #12 OR #13 OR #14 OR #15 OR #16) とした．MEDLINEにおいては，統制索引語を考慮し，(#1 OR #2 OR #3) AND (#4 OR #5 OR #6 OR #7 OR #8) とした．医中誌webにおいては，(#17 OR #18) AND (#19 OR #20 OR #21 OR #22) とした．最終検索は2013年8月6日に行った．検索から得られない文献を収集するため，ハンドサーチを行った．ハンドサーチは，検索により得られた文献のうち，2012年に出版されたレビュー文献の引用元に対し行った．

2. 包含基準

本研究における文献の包含基準は，1）タイトルおよび抄録に対するスクリーニング，2）全文論文に対する適格性の評価，の各段階に対し設定した．1）における包含基準は，①ヒトを対象とした研究であること，②英語または日本語で出版された文献であること，③原著論文であること，④臨床指標を用いて歯周病を測定していること，⑤循環器疾患の既往または発症をアウトカムにしていること，とした．2）における包含基準は，①歯周病の判定に，代表的な評価指標であるBOP，PPD，CALのうち，少なくとも一つを用いていること，②歯周病と脳血管疾患既往または発症の関連について，オッズ比（OR），リスク比（RR），ハザード比（HR）のいずれかが記載されていること，とした．

3. 一次研究の質の評価

包含基準を満たした文献に対し，質の評価を行った．質の評価は，観察研究の指針であるSTROBEから，方法に関わる7項目（研究デザイン：研究デザインを明記していること．セッティング：研究を行った国，年度，対象者が明記されていること．アウトカム指標の定義：アウトカムの測定方法が明記されていること．曝露指標の定義：曝露指標の測定方法が明記されていること．他の変数の定義：他の変数の測定方法が明記されていること．バイアスの検討：存在しうるバイアスに対し，考察がなされていること．統計方法：解析に使用した統計手法が明記されていること）を抜粋して使用した．各項目1点とし，得られた一次研究に対し，それぞれ0点～7点で評価を行った．

4. 解析

各一次研究において最も歯周病の重い群を患者群とし，最も健康な群を健常者群とした[4,12]．メタアナリシスを行う際，統合する一次研究のデザインが異なることは，異質性につながると考えられる．しかし，アウトカムの一般的な発生率が10%未満である場合，ORとRRは近似できるとされる[13]ため，本研究ではOR，RR，HRを同等に扱い，研究デザインの違いに関わらず統合を行った．このように，デザインの異なる一次研究を統合することは，過去のメタアナリシスにおいて，実際に行われている[14]．統合に際しては，95%CIから標準誤差(SE)を算出[15]，各文献の重みを$1/(SE)^2$とし，重み付けに使用した．

解析に使用する歯周病の測定指標は，臨床において広く用いられているBOP，PPD，CALとした．BOPは

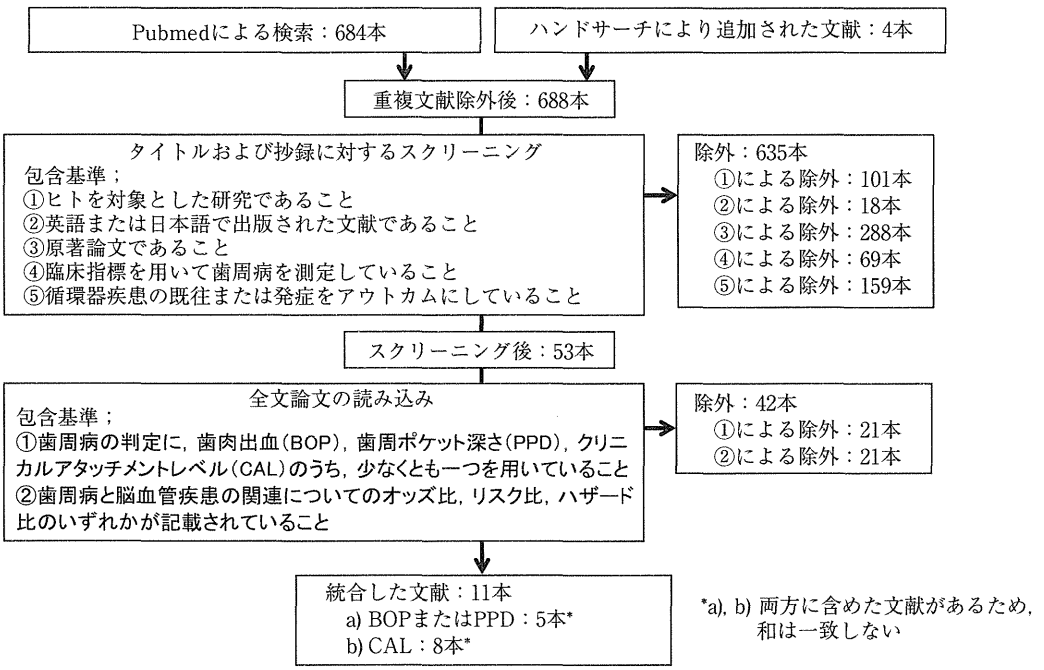

図1　文献検索フローチャート

測定時の炎症による歯周組織の脆弱性を表し，PPDは歯肉縁から歯周ポケット底までの距離を表す[7]．このため，BOPおよびPPDは測定を行った時点での歯肉の脆弱性や腫脹により測定値が変化する．一方，CALはセメントエナメル境から歯周ポケット底までの距離を表し，測定を行った時点での歯肉の脆弱性および腫脹の影響を受けない．この3指標の特性として，BOPおよびPPDは測定時の病変をより正確に反映する一方[7]，CALは測定時の病変よりも，過去の病態を表す蓄積指標としての特性をもつ[7,16,17]．これらの特性を考慮し，また，得られた一次研究のうちBOPを扱った研究が1本だけであったため，本研究では上記の3指標をa）測定時の炎症を反映する指標（BOP，PPD），b）測定時の炎症に左右されない指標（CAL）に分類，それぞれの脳血管疾患発症との関連を検討した．同じ測定指標を用いている一次研究でも，歯周病を分類するカットオフ値は異なっている．そこで，先行研究と同様に，最も歯周状態が良好な群に対する，最も歯周状態が悪い群の脳血管疾患のOR，RR，HRを解析に使用した[4]．

5.　出版バイアスの検討

メタアナリシス実施後，ファンネルプロットを作成，出版バイアスの検討を行った．出版バイアスの存在が疑われる場合の対応として，trim and fill法により未公表文献の推定を行った．

結　果

1.　各一次研究の特徴

キーワード検索により，684本の文献を得，ハンドサーチにより4本の文献を得た．計688本に対し，スクリーニングを行ったところ，635本が除外された（除外理由：①による除外101本，②による除外18本，③による除外288本，④による除外69本，⑤による除外159本）．53本の文献に，全文論文に対する適格性の評価を行ったところ，42本が除外された（除外理由：①による除外21本，②による除外21本）．最終的に11本の文献を得た[1,2,18-26]（図1）．

各一次研究の特徴を，表1に記す．横断研究4本，ケースコントロール研究5本，コホート研究2本であった．アウトカムである脳血管疾患は，出血性脳血管疾患のみが1本，虚血性脳血管疾患のみが3本，出血性および虚血性を統合したものが7本であった．歯周病の測定指標は，BOPを用いたものが1本，PPDを用いたものが4本，CALを用いたものが8本であり，2本がPPDとCALを併記していた．

2.　各一次研究の質の評価

各一次研究の質の評価結果を表2に示す．最低点は4点，最高点は7点，平均点は6.1点であった．アウトカムおよび曝露因子の定義はすべての一次研究が明記していた．明記している一次研究の数が最も少なかった項目

表1　得られた一次研究の特徴

著者	国	研究デザイン	N数	年齢	歯周病の測定指標	アウトカム	歯周病罹患者数（うち脳血管疾患ありの人数）	歯周病非罹患者数（うち脳血管疾患ありの人数）	オッズ比・リスク比（95% 信頼区間）	調整因子
Loesche 1998[23]	アメリカ	横断研究	401	60-	PPD CAL	H/I	28（14） 46（26）	96（50） 101（51）	0.96（0.92-1.01） 1.04（1.01-1.07）	#1, #8, #10, #11, #13, #17
Wu 2000[26]	アメリカ	コホート研究	9,962	25-74	PPD	H/I	NA	NA	1.66（1.15-2.39）	#1, #2, #3, #5, #6, #8, #9, #10, #11, #12, #13
Buhlin 2002[18]	スウェーデン	横断研究	1,577	41-84	BOP	H/I	NA	NA	1.83（0.78-4.31）	#1, #2, #5, #6, #7, #8
Elter 2003[1]	アメリカ	横断研究	6,436	NA	CAL	H/I	NA	NA	1.3（1.02-1.70）	#1, #2, #3, #5, #8, #10, #11, #12, #13, #14
Dörfer 2004[2]	ドイツ	ケースコントロール研究	95	18-75	CAL	I	51（33）	100（39）	7.38（1.55-15.03）	#1, #2, #4, #5, #8, #9, #11, #12, #14, #15, #16, #22, #23, #27
Grau 2004[19]	ドイツ	ケースコントロール研究	771	18-75	CAL	I	NA	NA	4.34（1.85-10.2）	#1, #2, #8, #11, #12, #15, #19, #21, #27
Lee 2006[22]	アメリカ	横断研究	5,123	60-	CAL	H/I	NA	NA	1.22（0.78-1.91）	#1, #8
Sim 2008[25]	韓国	ケースコントロール研究	479	40-79	CAL	H/I	178（131）	309（134）	3.97（2.26-6.97）	#1, #2, #5, #6, #8, #9, #10, #11, #12, #14, #18, #19, #24, #25, #26
Jimenez 2009[20]	アメリカ	コホート研究	1,137	48±8.8	PPD	H/I	264（25）	414（24）	1.07（0.59-1.93）	#1, #4, #5, #6, #7, #8, #9, #10, #11, #12, #13, #14, #18, #28
Kim 2010[21]	韓国	ケースコントロール研究	332	40-79	CAL	H	56（26）	200（59）	1.72（0.73-4.08）	#1, #2, #5, #6, #8, #9, #10, #11, #12, #18, #19, #20, #21, #22, #24, #25
Pradeep 2010[24]	インド	ケースコントロール研究	200	33-68	CAL PPD	I	45（33） 62（46）	69（22） 35（10）	2.4（0.3-17.1） 8.5（1.1-68.2）	#1, #2

PPD: Probing Pocket Depth　CAL: Clinical Attachment Level　BOP: Bleeding on Probing　I: 虚血性脳血管疾患　H: 出血性脳血管疾患
NA: 記載なし
#1 年齢，#2 性別，#3 人種，#4 職業，#5 教育歴，#6 収入，#7 婚姻状態，#8 喫煙，#9 飲酒，#10 Body Mass Index，#11 糖尿病，#12 高血圧，#13 血中コレステロール値，#14 心疾患既往，#15 脳血管疾患既往，#16 末梢動脈疾患既往，#17 全身疾患数，#18 口腔衛生状態，#19 歯科医院受診状態，#20 DMFT Index，#21 残存歯数，#22 心疾患の家族歴，#23 脳血管疾患の家族歴，#24 糖尿病の家族歴，#25 高血圧の家族歴，#26 心房細動の既往，#27 父親の職業，#28 空腹時血糖値

表2　一次研究の質の評価

項目	研究デザイン	セッティング	アウトカム定義	曝露指標定義	他の変数定義	バイアスの検討	統計方法	合計点
Loesche 1998[23]	×	×	○	○	○	×	○	4
Wu 2000[26]	○	○	○	○	○	○	○	7
Buhlin 2002[18]	○	○	○	○	○	×	○	6
Elter 2003[1]	○	○	○	○	○	×	○	6
Dörfer 2004[2]	○	○	○	○	○	○	○	7
Grau 2004[19]	○	×	○	○	○	○	○	6
Lee 2006[22]	○	○	○	○	×	○	○	6
Sim 2008[25]	○	○	○	○	○	×	○	6
Jimenez 2009[20]	○	○	○	○	○	×	○	6
Kim 2010[21]	○	○	○	○	○	○	○	7
Pradeep 2010[24]	○	○	○	○	○	×	○	6

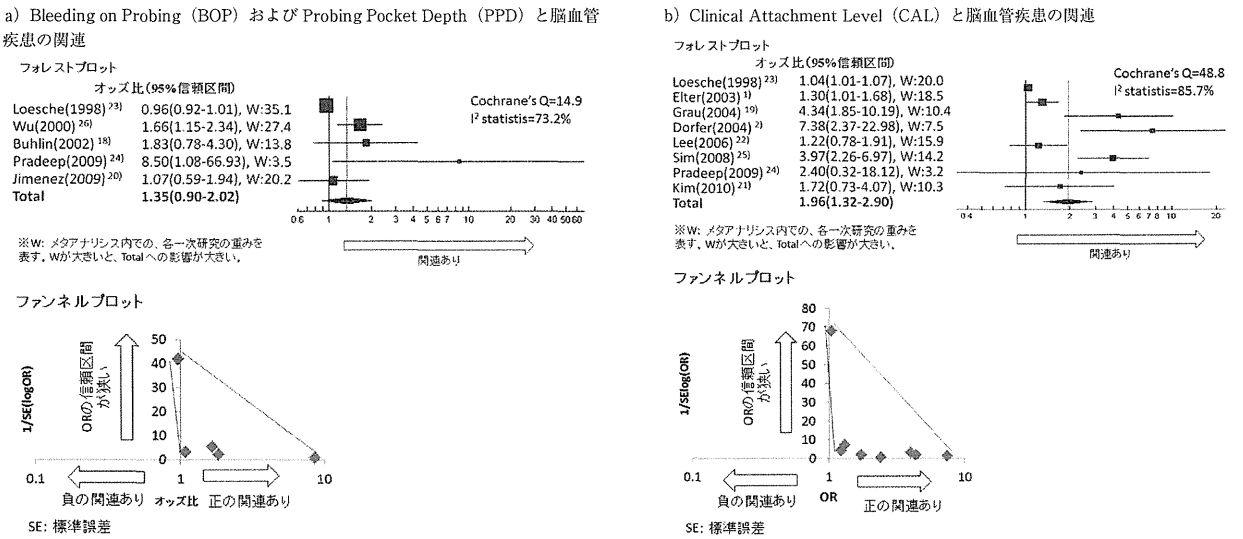

図2　メタアナリシス結果

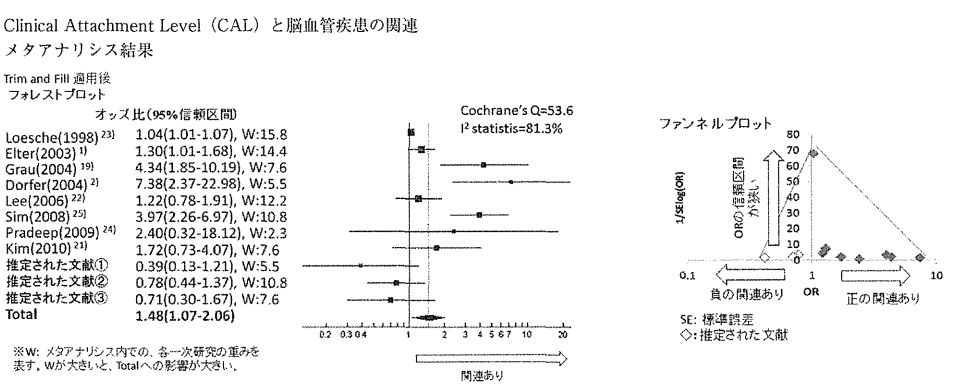

図3　trim and fill 適用後

はバイアスの検討であり，5本が明記していた．

3. メタアナリシス結果

a）測定時の炎症の影響を受ける歯周病の指標（BOP, PPD）と脳血管疾患の関連

BOP および PPD と脳血管疾患の関連を示した文献のフォレストプロットを，図2-a に示す．表1に示した各一次研究の特徴から，文献ごとの異質性の存在が推察されたため，ランダム効果モデルを適用した．解析の結果，歯周病と脳血管疾患の間に有意な関連は認められなかった（OR=1.35，95%CI；0.90-2.02）．統合した一次研究の統計学的異質性を示す I^2 値は 73.2% であった．

b）現在の炎症の影響を受けない歯周病の指標（CAL）と脳血管疾患の関連

CAL と脳血管疾患の関連を示した文献のフォレストプロットを，図2-b に示す．a）と同様に，文献ごとの異質性の存在が推察されたため，ランダム効果モデルを適用した．解析の結果，歯周病患者は脳血管疾患が多いという有意な正の関連を認めた（OR=1.96，95%CI；1.32-2.90）．統合した一次研究の統計学的異質性を示す I^2 値は 85.7% であった．

4. 出版バイアスの検討

a），b）それぞれに対し，ファンネルプロットを用いて出版バイアスの検討を行った（図2-a, b）．ファンネルプロットより，出版バイアスの存在が疑われた．出版バイアスを考慮し，未公表文献の推定を行った場合，OR は1に近づくことが予想される．このため，歯周病と脳血管疾患の間に有意な関連がみられた b）に対してのみ，trim and fill 法を適用した．

未公表文献の推定後のフォレストプロットおよびファンネルプロットを，図3に示す．未公表文献の推定後も b）は歯周病患者に脳血管疾患が多いという有意な正の関連を示した（OR=1.48，95%CI；1.07-2.06）．統合し

た一次研究の統計学的異質性を示す I^2 値は 81.3% であった．

考　察

本メタアナリシスにより，歯周病の測定指標によって，歯周病と脳血管疾患の関連が異なる可能性が示された．BOP や PPD は測定時の炎症の評価に有用な指標だが，初期の歯肉炎も，長期経過後の歯周炎と同様に評価する可能性がある．このため，BOP や PPD による評価では，歯周病に罹患していた期間は，正確には評価できないと考えられる．一方 CAL は，測定時の歯周の状態により影響を受けず，歯周病の過去の既往を適切に評価することができるとされている[7,16,17]．CAL により歯周病と判定された場合，ある程度の期間炎症が存在したことが推測される．このような特性の違いにより，BOP や PPD では有意な関連を示さなかった一方で，CAL は脳血管疾患との関連を示したと考えられる．

歯周病が脳血管疾患に影響を与えるメカニズムとして，1）歯周炎病変部局所で起きている免疫応答が，血管を通じて全身へ波及，動脈に炎症を引き起こし，動脈硬化が亢進し虚血に至る[27]，あるいは 2）動脈中に形成された粥状プラークの脆弱性が，歯周病由来の炎症により亢進，崩壊して血栓を形成し，虚血に至ることが挙げられている[6]．1）に関しては，全身の炎症マーカーと虚血性脳血管疾患発症は関連すること[28,29]，および歯周病により CRP 等の炎症マーカーが上昇することが報告されている[30-33]．2）に関しては，粥状プラークの脆弱性に影響を与える要因の一つに T 細胞やマクロファージ等の炎症性細胞が挙げられており[34]，歯周病による炎症との関連が示唆されている．しかし，これについては観察研究が中心であり，因果関係の証明には不十分とも指摘されている[7]．本研究の結果からは，CAL を用いて歯周病と判定された群は，長期間歯周組織に炎症が生じていたと推察されるため，1）における動脈硬化，2）における粥状プラークの脆弱性が，BOP や PPD により歯周病と判定された群に比べ，亢進していた可能性がある．

本研究にはいくつかの限界が存在する．第一に，統合した一次研究はすべて観察研究であり，ランダム化比較試験ではないため，交絡因子の影響を否定できない．しかし，本研究で統合された結果は，すべて年齢調整後の結果である．また，b）において，性別，喫煙，糖尿病，高血圧を調整している一次研究[1,2,19,21,25]のみを用いてサブグループ解析を行ったところ，歯周病と脳血管疾患の関連は有意なままであった（OR=2.89，95%CI；1.39-5.99）．しかしながら，他の交絡因子（社会経済状態，飲酒など）の存在は否定できないため，質の高いランダム化臨床試験の実施が望まれる．第二に，本研究において，統計学的異質性を示す I^2 値は a）で 73.2%，b）で 85.7% と，強い統計学的異質性を示した．しかし，統計学的異質性と研究特性の異質性は異なる概念であり，本研究では，炎症指標と蓄積指標を分けたことで，評価指標による異質性を，研究特性の観点から少なくできたと考えられる．第三に，本研究ではファンネルプロットを用いて出版バイアスを検討したが，一次研究が 10 本以下では，出版バイアスが実際に存在するのか，偶然の影響によるものなのか判定できないとの報告もある[35,36]．このため本研究で認められた出版バイアスが，偶然の影響による可能性もある．本研究では，出版バイアスが存在する可能性も考慮し，trim and fill 法を用いて未公表文献の影響も考慮した．CAL と脳血管疾患の関連は，trim and fill 法を用いた未公表文献の推定後も，有意なままであった．第四に，本研究における文献検索および一次研究の読み込みと質の評価は，一人の研究者によって行われた．このため，今回解析に含めた一次研究選択の妥当性には限界がある．

結　論

本研究は，歯周病と脳血管疾患の関連は，歯周病の測定指標により異なることを明らかにした．長期の歯周疾患罹患を反映する CAL は，脳血管疾患と有意な関連を示した．短期的な歯周疾患の罹患を示す可能性のある BOP や PPD は，脳血管疾患と有意な関連を示さなかった．脳血管疾患に限らず，全身の動脈硬化性疾患と歯周病の関連を検討する際には，歯周病の測定指標の特性を考慮した検討が必要である．

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著者への連絡先：松山祐輔　〒980-8575　宮城県仙台市青葉区星陵町4番1号　東北大学大学院歯学研究科口腔保健発育学講座国際歯科保健学分野
TEL：022-717-7639　FAX：022-717-7644
E-mail：matsuyama-thk@umin.org

Association between Periodontitis and Stroke
-A Meta-analysis Based on Periodontal Measurement Characteristics-

Yusuke MATSUYAMA[1], Jun AIDA[1], Kenji TAKEUCHI[2], Kanade ITO[1], Mieko NAKAYASU[3], Shihoko KOYAMA[1], Akihiro HASE[1], Toru TSUBOYA[1] and Ken OSAKA[1]

[1] Department of International and Community Oral Health, Tohoku University Graduate School of Dentistry
[2] Department of Preventive and Public Health Dentistry, Faculty of Dental Science, Kyushu University
[3] Health Promotion Division, Kita Ward Office, Hamamatsu-city

Abstract: From the year 2000, an increasing number of reports have focused on the association between periodontal and cardiovascular diseases. Periodontal measurements are carried out in a number of ways, and, therefore, the grading of periodontitis in each study may differ according to the measurements used. Some previous studies included meta-analyses; however, the heterogeneity of periodontal measurements was not taken into account. Therefore, we divided periodontal measurements which are taken more frequently into two groups: Group A, which included measurements reflecting inflammation on examination, as indicated by Bleeding on Probing (BOP) and Probing Pocket Depth (PPD); and Group B, which included measurements not reflecting inflammation on examination, indicated by Clinical Attachment Loss (CAL), and analyzed the pooled odds ratios (OR) of each group.

We conducted online and manual searches, which revealed 688 articles, of which 11 fulfilled the inclusion criteria. The measurements in Group A did not reveal a significant correlation between periodontal and cerebrovascular diseases (OR = 1.35; 95% confidence interval [CI], 0.90–2.02), while Group B measurements revealed a significant positive correlation between the 2 diseases (OR = 1.96; 95% CI, 1.32–2.90). To assess the existence of publication bias, we drew funnel plots, which revealed the possibility of publication bias. In order to analyze non-published articles, a trim and fill method was used to assess Group B. After putative non-published articles were included in the analysis, a significant correlation was observed between periodontitis and cerebrovascular diseases (OR = 1.48; 95% CI, 1.07–2.06).

Differences were observed between periodontitis and cerebrovascular disease due to different periodontal measurements. BOP and PPD cannot indicate the duration of periodontal disease, while CAL is a cumulative measure that can indicate the duration of periodontitis. Therefore, a stronger association may exist between CAL and cerebrovascular disease than that of BOP or PPD. This study suggests that the association between periodontal disease and stroke may differ according to periodontal measurements. Therefore, careful analysis is required while investigating the association between periodontal and cerebrovascular diseases, and further studies are warranted.

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Key words: Periodontal disease, Periodontitis, Gingivitis, Stroke, Meta-analysis

Reprint requests *to* Y. MATSUYAMA, Department of International and Community Oral Health, Tohoku University Graduate School of Dentistry 4-1, Seiryo-machi, Aoba-ku, Sendai, Miyagi 980-8575, Japan

TEL: +81-22-717-7639/FAX: +81-22-717-7644/E-mail: matsuyama-thk@umin.org

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NUTRITIONAL STATUS AND DYSPHAGIA RISK AMONG COMMUNITY-DWELLING FRAIL OLDER ADULTS

K. TAKEUCHI[1], J. AIDA[2], K. ITO[2], M. FURUTA[1], Y. YAMASHITA[1], K. OSAKA[2]

1. Section of Preventive and Public Health Dentistry, Division of Oral Health, Growth and Development, Faculty of Dental Science, Kyushu University, Japan; 2. Department of International and Community Oral Health, Tohoku University Graduate School of Dentistry, Japan. Corresponding author: Kenji Takeuchi, Section of Preventive and Public Health Dentistry, Division of Oral Health, Growth and Development, Faculty of Dental Science, Kyushu University, 3-1-1, Maidashi, Higashi-ku, Fukuoka-shi, Fukuoka-ken 812-8582, Japan, +81-92-642-6353, FAX: +81-92-642-6354, ktakeuchi@dent.kyushu-u.ac.jp

Abstract: *Objectives:* Although the presence of dysphagia is a key determinant of nutritional status among older adults, few studies have focused on the association between malnutrition and dysphagia risk in community-dwelling frail older adults. This study estimated the prevalence of malnutrition and quantified the association between malnutrition and dysphagia risk among community-dwelling older Japanese adults requiring long-term care. *Design:* Cross-sectional study. *Setting:* This study was conducted with the cooperation of the Japan Dental Association and local dental associations in all 47 prefectures from January to February 2012. *Participants:* Individuals aged ≥65 years capable of oral nutrient intake who were living at home and receiving home dental care and treatment. *Measurements:* Individual demographic characteristics and factors associated with health loss-related functional decline were obtained through interviews by home-visit dentists and self-administered questionnaires. Nutritional status and dysphagia risk were evaluated using the Mini Nutritional Assessment Short Form and the Dysphagia Risk Assessment for the Community-dwelling Elderly. *Results:* Among 874 respondents (345 men and 529 women), 24.6% were malnourished, 67.4% were at risk of malnutrition, and 8.0% were well nourished. Dysphagia risk was related to an increased likelihood of malnutrition at an old age, even after adjusting for covariates (PR = 1.30, 95% CI = 1.01–1.67). *Conclusion:* Malnutrition is highly prevalent among community-dwelling frail older adults, and dysphagia risk is independently associated with malnutrition. Dysphagia may be an important predictor of malnutrition progression in aged populations.

Key words: Older adults, nutritional status, dysphagia, community-dwelling.

Introduction

Dysphagia is the disorder of any part of the swallowing process and is associated with an increased risk of poor nutritional status (1, 2). Dysphagia can reduce or alter oral food and liquid intake, which can in turn contribute to the development of poor nutritional status. Dysphagia is particularly prevalent in older adults (3), because ageing reduces the swallowing function at the oral, pharyngeal, and esophageal stages (4–7). Age-related diseases and health conditions such as cancers of the aerodigestive tract, rheumatoid diseases, and neurologic and neuromuscular disorders are predisposing causes of dysphagia in older adults (2, 8). In addition, dysphagia often goes undetected because its signs and symptoms are clinically silent. As Japan's society is ageing, many healthy community-dwelling older adults may also have a risk of dysphagia and are unaware of it. The development of dysphagia results in reduced nutrient intake, which leads to malnutrition over time. Malnutrition, a complication of dysphagia, can increase the risks of morbidity, frailty, demands on healthcare systems, and longer hospital stays (9–11). In addition, malnutrition is a major predictor of decline in activities of daily living (ADL) and increased mortality (12, 13). Therefore, dysphagia may act as a trigger of the general decline in health among older adults.

A systematic review of stroke patients suggests individuals with dysphagia are more likely to be malnourished than those without dysphagia (1). This review also states the estimated prevalence of malnutrition in hospitalized patients ranges from 8.2% to 49.0%, depending on the type of hospital, demographic characteristics, and assessment tool used. In another cohort of older patients with pneumonia, the prevalence of malnutrition was 36.8% in older adults with dysphagia and 13.2% in adults with safe swallowing (14). In addition, these groups exhibited significant differences with respect to nutritional status. Although the frequent coexistence of poor nutritional status and dysphagia is well known in hospitalized and institutionalized patients (15, 16), little is known about the association between poor nutritional status and dysphagia in community-dwelling older adults. This study estimated the prevalence of malnutrition and assessed the association between malnutrition and dysphagia risk among community-dwelling older Japanese adults requiring long-term care. To our knowledge, this is the first large-scale study to analyze a randomly collected sample of almost 1,000 community-dwelling older individuals from Japan.

Methods

Study design and sample

This cross-sectional study was conducted with the cooperation of the Japan Dental Association and local dental associations in all 47 Japanese prefectures from January to February 2012. We requested the dental clinics throughout Japan belonging to local dental associations and providing home dental care and treatment to randomly select at least 1

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sample from among their patients. Patients aged ≥65 years capable of oral nutrient intake who were living at home and receiving home dental care and treatment were invited to participate in this study. Individuals not receiving public welfare service under the national long-term care insurance system were excluded. During home dental care and treatment, individual demographic characteristics and factors associated with the loss of health related to functional decline were obtained through interviews by dentists and self-administered questionnaires. Informed consent was obtained from all study subjects. As part of the Health Promotion Projects for Health of the Elderly by the Ministry of Health, Labour, and Welfare (Japan), this study was conducted in accordance with the ethical guidelines approved by the Ministry of Health, Labour, and Welfare.

Measurements

Nutritional status was evaluated using the Mini Nutritional Assessment Short Form (MNA-SF) (17, 18). According to the MNA-SF, nutritional status was divided into 3 categories: malnutrition (0–7 points), at risk of malnutrition (8–11 points), and well nourished (12–14 points). The outcome measure for the analysis using log-binomial regression was nutritional status, which was dichotomized into the following groups: normal nutritional status and malnutrition.

Dysphagia risk was evaluated using with the Dysphagia Risk Assessment for the Community-dwelling Elderly (DRACE) (19). The DRACE includes 12 questionnaires, each with a score between 0 and 2, and a cumulative score ranging from 0 to 24. A score ≥5 and above indicates at risk of dysphagia. Dysphagia risk was treated as the main predictor variable for nutritional status.

Nutritional status in community-dwelling older adults is associated with various factors such as sociodemographic characteristics, lifestyle and habits, oral health status, and chronic diseases (20–25). We included a wide range of independent variables outlined below as covariates in the log-binomial regression analysis. Sex, age, and living status were used as sociodemographic data. Age was categorized as 65–69, 70–74, 75–79, 80–84, 85–89, or ≥90 years. Living status was dichotomized as living alone or living with someone. Participation in leisure activities, smoking status, and number of meals per day were considered lifestyle and habit variables. Participation in leisure activities was assessed using the question, "Do you currently perform any leisure activities?" to which respondents answered "yes" or "no." Smoking status was categorized as current, ever, or non-smoker. The number of meals per day was dichotomized as <3 or ≥3. Dental prosthetic status and plaque volume were evaluated by dentists as predictors of oral health status. Dental prosthetic status was categorized as ≥10 remaining natural teeth with or without dentures, or <10 remaining natural teeth with or without dentures. Plaque volume was categorized as heavy, light, or none. Chronic medical conditions were assumed to be associated with both dysphagia risk and nutritional status. Information about the respondents' medical history of chronic diseases such as hypertension, cerebrovascular disease, heart disease, diabetes mellitus, respiratory disease, cancer, and hyperlipidemia was abstracted from the questionnaire, and each chronic disease was classified as present or absent.

Statistical analysis

Descriptive analyses were used to characterize the respondents. The $\chi 2$ test was used to evaluate whether the characteristics of respondents were associated with nutritional status. To examine the association between malnutrition and dysphagia risk, the prevalence ratios (PRs) and 95% confidence intervals (95% CIs) for malnutrition were calculated using log-binomial regression on the basis of the risk of dysphagia and covariates. A multivariate log-binomial regression model was created to adjust for possible confounding factors in the association between malnutrition and dysphagia risk. The multivariate analysis (model 2) included sex, age, and all other independent variables that were significantly associated with nutritional status at a significance level of $P < 0.20$ in the univariate analysis (model 1). The level of significance was set at 5% in all cases. All analyses were performed using SPSS statistical software version 21 (SPSS Inc., Chicago, IL, USA).

Results

A total of 1,195 patients from 548 dental clinics in 42 prefectures in Japan participated in the present survey. Of them, 138 without long-term care were excluded, leaving 1,057 respondents. After excluding respondents with missing responses for information on sex, age, the DRACE, or the MNA-SF, the remaining 874 respondents were included in the analysis. The characteristics of all respondents (N = 874; average age, 80.7 ± 7.9 years for men and 82.9 ± 7.5 years for women) are presented in Tables 1 and 2. Of the respondents, 24.6% (95% CI = 21.7–27.5) were malnourished, 67.4% (95% CI = 64.3–70.5) were at risk of malnutrition, and 8.0% (95% CI = 6.2–9.8) were well nourished. Among respondents with malnutrition, 141 (65.6%) were at risk of dysphagia. Sociodemographic data, lifestyle and habits, oral health status, and chronic medical conditions by nutritional status are also shown in Tables 1 and 2. The respondents at risk of dysphagia had a significantly higher prevalence of malnutrition than respondents not at risk. The prevalence of malnutrition was significantly lower among subjects who participated in leisure activities than those who did not. The prevalence of malnutrition was also significantly lower among respondents with clinical features of hyperlipidemia than among those with no clinical features of hyperlipidemia.

Table 3 shows the associations of nutritional status with the risk of dysphagia, socio-demographic data, lifestyle and habits, oral health status, and chronic medical conditions, as determined using log-binomial regression. There were

significant associations between nutritional status and the risk of dysphagia, participation in leisure activities, plaque volume, and hyperlipidemia (model 1). These associations remained significant after adjusting for covariates (model 2). In model 2, respondents at risk of dysphagia had a significantly higher PR (PR = 1.30, 95% CI = 1.01–1.67) for malnutrition than respondents not at risk of dysphagia. Model 2 also shows respondents participating in leisure activities had a significantly lower PR (PR = 0.67, 95% CI = 0.45–0.98) for malnutrition than non-participation. Respondents with heavy plaque had a significantly higher PR (PR = 1.52, 95% CI = 1.03–2.24) for malnutrition than respondents with no plaque. Moreover, respondents with hyperlipidemia had a significantly lower PR (PR = 0.22, 95% CI = 0.06–0.83) for malnutrition than respondents with no hyperlipidemia.

Table 1
Comparison of characteristics of respondents by nutritional status (n = 874)

	N=874	% of malnutrition	P-value
Sex			0.889
Men	345	24.3	
Women	529	24.8	
Age			0.873
65-69	59	23.7	
70-74	94	20.2	
75-79	164	25.0	
80-84	212	23.6	
85-89	196	27.0	
≧90	149	25.5	
Living status			0.815
Alone	192	24.0	
With someone	682	24.8	
Participation in leisure activities			0.006
Yes	151	15.9	
No	714	26.5	
Missing	9		
Smoking status			0.657
Current smoker	19	15.8	
Ever smoker	261	24.9	
Non-smoker	588	25.0	
Missing	6		
Number of meals per day			0.083
< 3	44	13.6	
≧3	830	25.2	
Dental prosthetic status			0.667
≧10 remaining natural teeth with dentures	248	23.8	
≧10 remaining natural teeth without dentures	206	26.7	
< 10 remaining natural teeth with dentures	386	24.6	
< 10 remaining natural teeth without dentures	20	15.0	
Missing	14		
Plaque volume			0.061
Heavy	232	28.0	
Light	451	25.5	
None	167	18.0	
Missing	24		
Risk of dysphagia			0.020
At risk	514	27.4	
Non-risk	360	20.6	

Table 2
Comparison of chronic medical conditions of respondents by nutritional status (n = 874)

	N=874	% of malnutrition	P-value
Hypertension			0.957
Yes	294	24.5	
No	580	24.7	
Cerebrovascular disease			0.165
Yes	252	27.8	
No	622	23.3	
Heart disease			0.349
Yes	144	21.5	
No	730	25.2	
Diabetes mellitus			0.494
Yes	118	27.1	
No	756	24.2	
Respiratory disease			0.413
Yes	55	20.0	
No	819	24.9	
Cancer			0.734
Yes	41	26.8	
No	833	24.5	
Hyperlipidemia			0.005
Yes	38	5.3	
No	836	25.5	

Discussion

The present study indicates dysphagia is significantly associated with malnutrition in a representative sample of community-dwelling frail men and women aged ≥65 years in Japan. This significant association was observed even after adjusting for possible confounders. Importantly, the combined prevalence of malnutrition and risk of malnutrition was >90.0%. To our knowledge, no published reports indicate such a substantial percentage of community-dwelling frail older adults in Japan require assistance to improve their nutritional status.

Similar to the present findings, previous studies indicate the risk of dysphagia is associated with a higher PR for malnutrition as indicated by the MNA or MNA-SF among community-dwelling older adults or frail older adults (22, 26, 27). A cohort study suggests individuals with clinical signs of dysphagia have an increased risk or are at risk of malnutrition at a 1-year follow-up examination (26). However, in the present study, the prevalences of malnutrition (24.6%) and at risk of

malnutrition (67.4%) were higher compared to those in a previous review of community-dwelling frail older adults (28). Recent studies in Japan report that the prevalences of malnutrition and at risk of malnutrition are 13.3–14.0% and 51.7–55.2%, respectively (22, 27). The characteristics of the respondents can explain the variability of these results. The respondents investigated in the present study were receiving home dental care and treatment; therefore, they were likely to have a very low ADL level. A decline in ADL is significantly associated with an increased risk of malnutrition according to the MNA (29–31). Therefore, the lower functional ability of the respondents in the present study may be related to the high prevalences of malnutrition and at risk of malnutrition.

In addition to the association between nutritional status and its main predictor variable, dysphagia, nutritional status was significantly associated with other covariates. Participation in leisure activities was significantly associated with nutritional status. Participation in leisure activities provides opportunities for social interaction. Decreased social interaction resulting from decreased social participation may have negative implications for the eating habits of older adults. Thus, in the current aging society, social participation is important for preventing malnutrition, because many older retired people are assumed to have decreased opportunities for social interaction. In addition, hyperlipidemia was significantly associated with malnutrition. Previous studies showed that the prevalence of hyperlipidemia was significantly lower in adults with low nutrient conditions than in those with other nutrient conditions (32, 33); this is generally concordant with the results of the present study. Furthermore, malnutrition was significantly associated with dental plaque accumulation. A cross-sectional study reports poor oral hygiene based on plaque score is associated with low nutritional status (34). The results of the present study support the view that older adults with

Table 3
Association of nutritional status with risk of dysphagia and covariates determined by using logistic regression

	Model 1		Model 2	
	Crude PR (95% CI)	**P-value**	**Multivariate PR (95% CI)**	**P-value**
Risk of dysphagia (ref. Non-risk)	1.33 (1.04-1.71)	0.022	1.30 (1.01-1.67)	0.045
Sex (ref. Men)	1.02 (0.80-1.29)	0.889	1.11 (0.87-1.41)	0.422
Age (ref. 65-69)				
70-74	0.85 (0.46-1.57)	0.606	0.77 (0.42-1.40)	0.387
75-79	1.05 (0.62-1.79)	0.847	1.03 (0.61-1.72)	0.915
80-84	0.99 (0.59-1.67)	0.982	0.96 (0.57-1.60)	0.869
85-89	1.14 (0.68-1.90)	0.617	1.08 (0.65-1.78)	0.777
≧90	1.07 (0.63-1.83)	0.791	1.02 (0.60-1.74)	0.928
Living status (ref. With someone)	0.97 (0.73-1.28)	0.816		
Participation in leisure activities (ref. Non-participation)	0.60 (0.41-0.88)	0.010	0.67 (0.45-0.98)	0.037
Smoking status (ref. Non-smoker)				
Current smoker	0.63 (0.22-1.80)	0.390		
Ever smoker	1.00 (0.77-1.28)	0.976		
Number of meals per day (ref. < 3)	1.85 (0.87-3.92)	0.110	1.58 (0.75-3.34)	0.232
Dental prosthetic status (ref. ≧10 remaining natural teeth with dentures)				
≧10 remaining natural teeth without dentures	1.12 (0.82-1.54)	0.476		
< 10 remaining natural teeth with dentures	1.03 (0.78-1.37)	0.814		
< 10 remaining natural teeth without dentures	0.63 (0.22-1.83)	0.397		
Plaque volume (ref. None)				
Heavy	1.56 (1.06-2.29)	0.023	1.52 (1.03-2.24)	0.037
Light	1.42 (0.99-2.04)	0.057	1.39 (0.97-2.01)	0.075
Hypertension (ref. No)	0.99 (0.78-1.27)	0.957		
Cerebrovascular disease (ref. No)	1.19 (0.93-1.52)	0.161	1.19 (0.93-1.53)	0.164
Heart disease (ref. No)	0.85 (0.61-1.20)	0.357		
Diabetes mellitus (ref. No)	1.12 (0.81-1.55)	0.489		
Respiratory disease (ref. No)	0.80 (0.47-1.38)	0.427		
Cancer (ref. No)	1.10 (0.65-1.84)	0.731		
Hyperlipidemia (ref. No)	0.21 (0.05-0.80)	0.022	0.22 (0.06-0.83)	0.026

PR = prevalence ratio; CI = confidence interval.

compromised oral hygiene have reduced nutrient intake and subsequently become malnourished.

The present findings have implications in public health. Early detection of decreased nutritional status should be a priority in healthcare systems because of the high prevalence of malnutrition and risk of malnutrition among community-dwelling older adults. The risk of dysphagia based on the DRACE is possibly a contributing factor to decreased nutritional status. Dysphagia refers to difficulty swallowing, including oropharyngeal or esophageal problems such as physiological and biomechanical impairments to bolus flow; in turn, this reduces oral feeding and may result in malnutrition (8). Therefore, increasing attention to the nutritional status of groups at risk of dysphagia as part of a population-at-risk approach may prevent malnutrition among community-dwelling older adults.

More than half of the respondents had a risk of dysphagia. Therefore, the present results support the routine use of the DRACE as a screening method for determining dysphagia. Thus, routine screening for dysphagia in community-dwelling older adults is an important responsibility of healthcare systems not only for trained healthcare professionals, but also for caregivers. The DRACE can be implemented easily by all caregivers as well as healthcare professionals; this ease of use is a practical advantage during screening.

Despite its strengths, the present study also has several limitations. First, this study design was cross-sectional. Therefore, it was not possible to generate any statements on causation or to exclude the possibility of reverse causation. Accordingly, longitudinal or interventional studies are required to determine causal relationships between malnutrition and dysphagia in community-dwelling older adults. Second, socioeconomic status variables such as income, education, and occupation were not included in the analysis. Several studies report socioeconomic status is associated with nutritional status among community-dwelling older adults (35–38). For example, education level as indicated by years of schooling is significantly associated with MNA scores (35, 36). Education level is also associated with income and lifestyle, which in turn affects the nutritional status of community-dwelling older adults. Finally, the characteristics of respondents represent a potential limitation of the present study. As mentioned earlier, the respondents might have had a lower ADL level compared to that in average community-dwelling frail older adults. Therefore, caution should be exercised when extrapolating the present findings to independently living frail older adults in Japan. However, the relatively large sample including respondents from almost all prefectures of Japan provides some assurance of external validity. Therefore, the population sample could be considered a strength of this study.

Conclusion

The present results indicate the overwhelming majority of community-dwelling frail older adults are malnourished or are at risk of malnutrition. In addition, the PRs for malnutrition increase in the presence of dysphagia. These findings suggest dysphagia may be an important predictor of the progression of malnutrition in aged populations.

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