A Cross-sectional Multivariate Analysis of the Relationship Between Dental Health and Metabolic Syndrome

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Objective : The aim of the present study was to investigate the relationship between periodontal diseases and metabolic syndrome (MetS) with a combination of specific health and dental check-ups based on a cross-sectional study.

Methods : Data obtained from 985 subjects aged 30 and older who participated in specific health check-ups and simultaneous dental check-ups in 2014 were reviewed and investigated.

Results : An assessment of correlation coefficients among risk factors revealed that age and smoking were confounding factors for the number of MetS components and dental periodontitis. A multivariate analysis revealed that periodontitis correlated with each component of MetS (obesity (Community Periodontal Index (CPI) code 0 vs code 1, odds ratio (OR) : 1.34, 95 % confidence interval (CI) : 0.67-2.57, code 0 vs code 2, OR : 1.20, 95 % CI : 0.81-1.78, code 0 vs code 3, OR : 1.70, 95 % CI : 1.05-2.70, and code 0 vs code 4, OR : 1.01, 95 % CI : 0.35-2.56, $p < 0.05$), hypertension (CPI code 0 vs code 1, OR : 1.02, 95 % CI : 0.57-1.81, code 0 vs code 2, OR : 1.60, 95 % CI : 1.14-2.26, code 0 vs code 3, OR : 1.29, 95 % CI : 0.83-1.99, and code 0 vs code 4, OR : 1.83, 95 % CI : 0.7-4.64, $p < 0.05$), and hyperglycemia (CPI code 2 vs 3, OR : 1.52 95 % CI : 1.00-2.31, code 2 vs 4, OR : 1.29 95 % CI : 0.56-2.87, $p = 0.07$)) in considering common risk factors.

Conclusions : Periodontitis and MetS might be generated from the same common risk factors, including age and smoking. However, periodontitis may also have some direct relationship with MetS. MetS and periodontitis should be evaluated collaboratively. *Shinshu Med J 67 : 167―181, 2019*

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Key words : periodontal disease, metabolic syndrome, cross-sectional study, community periodontal index, common risk factor

I Introduction

Metabolic syndrome (MetS) is a complex collection of components that are considered to arise from visceral fat-type obesity, involving hypertension and the abnormal metabolism of glucose and lipids. MetS is associated with an increased risk of cardiovascular disease and type 2 diabetes mellitus (DM). Risk factors for MetS include obesity, physical inactivity, and insulin resistance, while aging, hormonal imbalances, and a genetic predisposition have also been shown to play contributing roles[1)2)]. In the USA, the estimated prevalence of MetS was reported to be 34.7 % in 2011-2012[3)]. Furthermore, the prevalence of MetS was found to increase with age : 18.3 % of 20-39-year-old adults and 46.7 % of those aged 60 years or older[3)]. In middle-aged Japanese individuals, the prevalence of MetS was reported to be 14.9 %[4)].

MetS is considered to originate from a pro-inflammatory state as a result of the effects of insulin resistance[5)]. Insulin resistance is associated with an increased body mass index and waist circumference, both of which reflect increased levels of adiposity and the deposition of visceral adipose tissue. Adipocytes and infiltrating macrophages pro-

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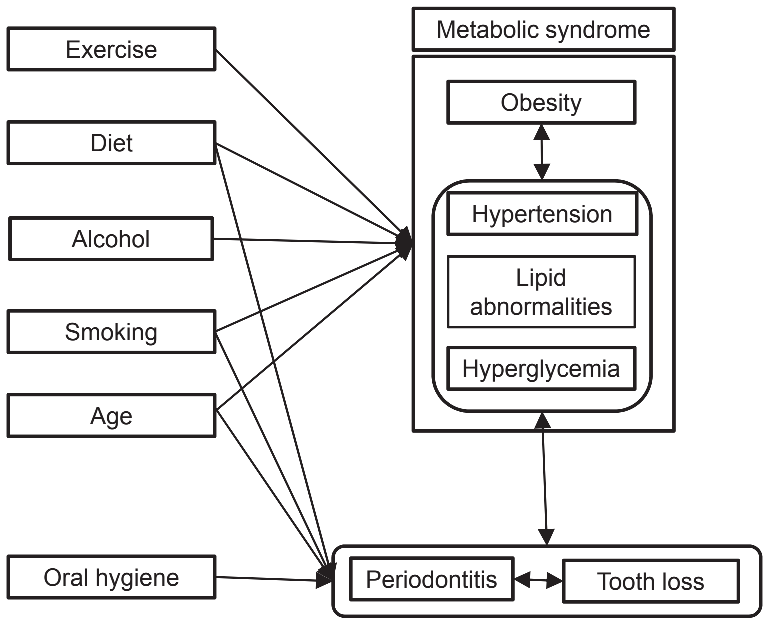

Fig. 1 Schema of the common risk factor approach

duce cytokines, such as tumor necrosis factor-alpha, interleukins, and other signaling molecules associated with pro-inflammatory activity and insulin resistance[6]. The circulating levels of these inflammatory molecules are elevated in individuals with obesity and insulin resistance[7]. Furthermore, insulin resistance may be associated with oxidative stress[5]. Systemic oxidase stress was shown to be significantly greater in individuals with MetS than in those without[8].

Close interactive relationships have been reported between periodontitis and MetS[1)2)5)8)-15)]. In a systematic review, being overweight, obesity, weight gain, and an increased waist circumference were proposed as risk factors for periodontitis[16]. The prevalence of MetS was higher in individuals with severe periodontitis (37 %) than in those with no/mild periodontitis (18 %)[9]. In a comprehensive health examination of 6,421 Japanese individuals (aged between 34 and 77 years), those with a deep periodontal probing depth (PD) and clinical attachment level (CAL) or with moderate PD and CAL had a significantly higher odds ratio for MetS[4]. Furthermore, the prevalence of a high Community Periodontal Index (CPI) code was significantly higher in individuals with three components of MetS and those with four or five components than in those without positive components[11)17)]. Many chronic diseases, including periodontitis, hypertension, and diabetes mellitus, are influenced by common risk factors (**Fig. 1**, such as diet, smoking, alcohol, exercise, and stress[18]). Therefore, when the relationship between periodontal diseases and MetS is being investigated, it is important to consider the impact of these common risk factors.

Since 2008, the Ministry of Health, Labour and Welfare of Japan has obliged the insured and their dependents aged>40 years to receive specific health check-ups focusing on visceral -fat obesity[19]. However, dental check-ups are not included in specific health check-ups. In the present study, we performed dental check-ups on individuals who participated in specific health check-ups. We examined the cross-sectional relationship between dental health and MetS in the light of common risk factors.

Ⅱ Materials and Methods

This study protocol was approved by the Committee on Medical Research of Shinshu University (#2775).

In 2010, 2,716 individuals with national health insurance aged 30 and older (including self-employed workers, farmers, and the elderly) underwent specific health check-ups in Shiojiri city, Nagano Prefecture, Japan. Of these, 985 individuals (461 men and 524 women) who agreed to dental check-ups were included as subjects in the present study. Written informed consent was obtained from all subjects.

A Medical check-ups

Specific health check-ups were conducted following the standard program supplied by the Ministry of Health, Labour and Welfare of Japan (2013)[20]. They included an interview on lifestyle habits and systemic disease treatment status, measurements of height, weight, waist circumference, and blood pressure, and blood tests. Subjects were asked about their recent (within one year) smoking habit (yes or no). The frequency of alcohol intake and the amount were evaluated and classified into four categories (non-drinker, occasional drinker, daily light-moderate drinker of less than 43 g of alcohol, and daily heavy drinker). Individuals were also asked whether they ate midnight snacks (yes or no) and performed regular exercise (yes or no). Blood tests included measurements of triglycerides, low/high-density lipoprotein cholesterol, blood sugar, hemoglobin A1c (HbA1c), and creatinine level. Regular exercise was defined light-sweat exercise of more than 30 minutes for more than 2 days a week, for 1 year or more[20].

The Japanese criteria (modification of the International Diabetes Federation (IDF) criteria[21]) for MetS were utilized in the present study : (a) dyslipidemia (triglycerides ≥ 150 mg per dL and/or high-density lipoprotein cholesterol (HDL-C) < 40 mg per dL or specific treatments for these lipid abnormalities) ; (b) hypertension (systolic blood pressure ≥ 130 mmHg and/or diastolic blood pressure ≥ 85 mmHg or the treatment of previously diagnosed hypertension) ; and (c) hyperglycemia (fasting plasma glucose ≥ 110 mg/dL, HbA1c (NGSP) ≥ 5.6 %, or a specific treatment for diabetes mellitus (DM))[22)-25]. Waist circumference was measured at the navel in a standing position, and visceral fat accumulation was assessed as being positive at a waist circumference ≥ 85 cm for men and ≥ 90 cm for women.

B Dental check-ups

Each individual underwent dental check-ups that evaluated dental and periodontal conditions by trained dentists. Seven trained dentists participated in this study and unification of the dental examination method had been carried out prior to the study. Dental check-ups included the inspection of dental and periodontal tissues as well as oral hygiene. The presence of periodontal diseases was evaluated according to the World Health Organization (WHO) CPI criteria[26]. CPI was originally developed by WHO to measure community oral health and commonly used for periodontal screening. CPI criteria were defined from Code 0 to Code 4 (Code 0 : healthy periodontal conditions ; Code 1 : gingival bleeding on probing ; Code 2 : calculus and bleeding ; Code 3 : periodontal pocket 4-5 mm ; and Code 4 : periodontal pocket ≥ 6 mm[26,27]. PD was measured using standard WHO probes and recorded according to the periodontal disease examination manual proposed by the Ministry of Health, Labour and Welfare of Japan (2015)[28].

Oral hygiene was assessed by dentists and classified into three categories (good : clean and no food particles or tartar in mouth or dentures ; fair : food particles/tartar/plaque in 1-2 areas of the mouth or small area of denture or halitosis ; or poor : food particles/tartar/plaque in most areas of the mouth or on most of dentures or severe halitosis), according to the Oral Health Assessment[29].

C Statistical analyses

A univariate analysis was performed with the Wilcoxon rank-sum test, Kruskal Wallis test, chi-square goodness of fit test, and the chi-squared test. A multivariate analysis was performed with a multivariate logistic regression. Statistical analyses were performed using JMP ver.12 (SAS Institute Inc., North Carolina, USA). P values < 0.05 were considered to be significant.

Ⅲ Results

A Subject characteristics

Among 1,027 individuals who underwent specific health check-ups in 2014, 985 (461 men and 524 women) who agreed to dental check-ups were included as subjects in the present study. The mean age ± standard deviation (SD) of subjects was 59.4 ± 12.1 year-old. Sixty subjects (6.1 %) had a recent smoking habit within 1 year. Four hundred and eighty individuals (48.7 %) did not drink alcohol. The mean number of present teeth was 25.5 ± 5.3 and the mean number of unreplaced missing teeth was 2.26 ±4.67. Oral hygiene was good in 598 subjects (60.7 %), fair in 344 (34.9 %), and poor in 51 (5.2 %). The CPI code was 0 in 321 subjects (32.6 %), 1 in 69 (7.0 %), 2 in 368 (37.4 %), 3 in 163 (16.5 %), and 4 in 29 (2.9 %). PD was 1–3 mm in 778 subjects (79.0 %), 4–5 mm in 163 (16.5 %), and ≥6 mm in 29 (2.9 %).

The correlation matrix (Spearman's rank correlation coefficient) of risk factors is shown in **Table 1**. Significant and moderate to strong correlations (r>0.3) were observed between sex and alcohol drinking behavior, between age and number of present teeth, between oral hygiene and CPI code or PD, between CPI and PD, and between the number of present teeth and that of unreplaced missing teeth. Weak (r<0.3) but significant correlation was found between sex, age, or recent smoking habit and dental conditions (CPI/PD, oral hygiene, and number of present or unreplaced missing teeth). Thereafter, multivariate analysis was carried out considering the multicollinearity.

B Relationship between dental conditions and the number of positive components of MetS (Table 2)

The relationship between dental conditions and the number of positive components of MetS (waist circumference, hypertension, lipid abnormalities, and hyperglycemia) was analyzed. A positive number correlated with sex (p<0.01), age (p<0.01), a recent smoking habit (p<0.01), regular exercise (p<0.01), oral hygiene (p<0.01), CPI (p<0.01), PD (p<0.01), and the number of present (p<0. 01) and unreplaced missing teeth (p<0.01) in the univariate analysis. The multivariate analysis revealed that the number of positive components correlated with sex (p<0.01), age (p<0.01), and a recent smoking habit (p<0.01). Female and advanced age affected the increase of the number of positive components of MetS. Individuals without recent smoking habit had less number of positive components of MetS. The age had multicollinearity. Therefore, when age was removed from the multivariate logistic model, the number of unreplaced missing teeth was associated with the number of positive MetS components.

Table 1 Correlation matrix (Spearman's rank correlation coefficient) of risk factors

	Sex	Age	Recent smoking habit	Alcohol intake	Midnight snacking	Regular exercise	Oral hygiene	CPI code	Pocket depth	No. of present teeth	No. of unreplaced missing teeth
Sex	–	0.0278	0.1950*	0.3325*	−0.0383	0.0596	0.2636*	0.1307*	0.0895*	0.0898*	0.033
Age		–	−0.0274	−0.0232	−0.1252*	0.1679*	0.1589*	0.1048*	0.1786*	−0.4647*	0.1762*
Recent smoking habit			–	0.1182*	0.0569	−0.0311	0.1502*	0.1549*	0.1359*	−0.0676**	0.0888*
Alcohol intake				–	−0.0106	0.0732**	0.0307	0.0123	0.0177	0.1024*	−0.0642**
Midnight snacking					–	−0.0751**	0.0321	−0.0216	0.3987	0.0182	0.0018
Regular exercise						–	−0.0034	−0.0198	0.0052	−0.0774**	0.0251
Oral hygiene							–	0.343*	0.3046*	−0.1128*	0.1522*
CPI code								–	0.7319*	−0.0378	0.1111*
Pocket depth									–	−0.122*	0.1045*
Number of present teeth										–	−0.3496*
No. of unreplaced missing teeth											–

*: p<0.01 **: p<0.05

Table 2 Association between number of metabolic syndrome (MetS) components and independent variables

		No. of MetS components					Result of univariate analysis (p value)		Result of ordered logistic regression analysis (p value)
		0 (325)	1 (285)	2 (207)	3 (124)	4 (44)			
Sex	Female (524)	205	153	104	52	10	<0.01	Chi-squared test	<0.01
	Male (461)	120	132	103	72	34			
Age	Mean (SD)	52.4 (13.3)	61.7 (10.1)	63.7 (9.6)	63.5 (10.0)	64.4 (6.9)	<0.01	Wilcoxon test	<0.01
Recent smoking	No (925)	323	270	183	108	41	<0.01	Goodness test of fit for chi-square	<0.01
	Yes (60)	2	15	24	16	3			
Alcohol drinking behavior	No (480)	151	139	113	58	19	NS	Goodness test of fit for chi-square	NS
	Chance (297)	110	88	54	33	12			
	Daily, right-moderate (171)	53	50	34	23	11			
	Daily, heavy (37)	11	8	6	10	2			
Midnight snacking	No (874)	286	254	182	112	40	NS	Goodness test of fit for chi-square	NS
	Yes (111)	39	31	25	12	4			
Regular exercise	No (666)	229	199	126	74	38	<0.01	Goodness test of fit for chi-square	NS
	Yes (319)	96	86	81	50	6			
Oral hygiene	Good (589)	220	162	118	72	17	<0.01	Goodness test of fit for chi-square	NS
	Fair (344)	93	110	75	45	21			
	Poor (51)	12	13	13	7	6			
	missing data (1)			*1*					
CPI	0 (321)	125	81	65	39	11	<0.01	Goodness test of fit for chi-square	NS
	1 (69)	23	24	12	7	3			
	2 (388)	135	120	71	45	17			
	3 (163)	38	44	47	25	9			
	4 (29)	1	13	8	4	3			
	missing data (15)	*3*	*3*	*4*	*4*	*1*			
Pocket depth	1-3 mm (778)	283	225	148	91	31	<0.01	Goodness test of fit for chi-square	NS
	4-5 mm (163)	38	44	47	25	9			
	6=<mm (29)	1	13	8	4	3			
	missing data (15)	*3*	*3*	*4*	*4*	*1*			
No. of present teeth	Mean (SD)	26.5 (4.6)	25.6 (5.1)	24.4 (6.0)	24.2 (6.3)	25.9 (4.4)	<0.01	Wilcoxon test	NS
No. of un-replaced missing teeth	Mean (SD)	0.2 (0.9)	0.4 (1.2)	0.8 (2.9)	0.7 (2.0)	0.6 (1.4)	<0.01	Wilcoxon test	NS

*1 : Presence of MetS>absence of or potential for Mets

NS : Not significant.

C Relationship between dental conditions and obesity (waist circumference) (Table 3)

In the univariate analysis, obesity correlated with sex ($p<0.01$), a recent smoking habit ($p<0.01$), alcohol intake ($p<0.05$), oral hygiene ($p<0.01$), CPI ($p<0.05$), PD ($p<0.05$), and the number of unreplaced missing teeth ($p<0.05$). Regular exercise tended to be associated with obesity ($p=0.079$). The multivariate analysis revealed that obesity correlated with sex (female vs male odds ratio (OR) : 4.06, 95 % confidential interval (CI) : 2.90-5.74, $p<0.01$), regular exercise (no vs yes, OR : 1.51, 95 % CI : 1.06-2.16, $p<0.05$), and CPI (code 0 vs code 1, OR : 1.34, 95 % CI : 0.67-2.57, code 0 vs code 2, OR : 1.20, 95 % CI : 0.81-1.78, code 0 vs code 3, OR : 1.70, 95 % CI : 1.05-2.70, and code 0 vs code 4, OR : 1.01, 95 % CI : 0.35-2.56, $p<0.05$). These results suggested that male gender, no regular exercise, and periodontitis was associated with obesity.

D Relationship between dental conditions and hypertension (Table 4)

In the univariate analysis, hypertension correlated with sex ($p<0.05$), age ($p<0.01$), a recent smoking habit ($p<0.01$), oral hygiene ($p<0.01$), CPI ($p<0.01$), PD ($p<0.01$), and the number of unreplaced missing teeth ($p<0.01$). The multivariate analysis revealed that hypertension correlated with age (OR : 1.08, 95 % CI : 1.07-1.10, $p<0.01$), a recent smoking habit (no vs yes, OR : 2.23, 95 % CI : 1.16-4.16, $p<0.05$), CPI (code 0 vs code 1, OR : 1.02, 95 % CI : 0.57-1.81, code 0 vs code 2, OR : 1.60, 95 % CI : 1.14-2.26, code 0 vs code 3, OR : 1.29, 95 % CI : 0.83-1.99, and code 0 vs code 4, OR : 1.83, 95 % CI : 0.7-4.64, $p<0.05$), and the number of unreplaced missing teeth (OR : 1.12, 95 % CI : 1.003-1.26, $p<0.05$). These results revealed that individuals with advanced age, recent smoking habit, periodontitis, and large number of unreplaced missing teeth were associated with hypertension.

E Relationship between dental conditions and lipid abnormalities (Table 5)

Lipid abnormalities correlated with sex ($p<0.01$), age ($p<0.01$), a recent smoking habit ($p<0.01$), alcohol intake ($p<0.05$), CPI ($p<0.05$), PD ($p<0.05$), and the number of residual teeth ($p<0.01$) and unreplaced missing teeth ($p<0.01$) in the univariate analysis. Lipid abnormalities were also associated with regular exercise ($p=0.07$). The multivariate analysis revealed that lipid abnormalities correlated with age (OR : 1.03, 95 % CI : 1.02-1.05, $p<0.01$) and a recent smoking habit (no vs yes, OR : 2.90, 95 % CI : 1.68-5.05, $p<0.001$). Furthermore, alcohol intake was associated with lipid abnormalities (non-drinker vs occasional drinker, OR : 0.69, 95 % CI : 0.50-0.69, non-drinker vs light-moderate drinker, OR : 0.80, 95 % CI : 0.5-1.17, non-drinker vs heavy drinker, OR : 1.16, 95 % CI : 0.57-2.35, $p=0.051$). These results revealed that individuals of advanced age and with a recent smoking habit were associated with lipid abnormalities.

F Relationship between dental conditions and hyperglycemia (Table 6)

In the univariate analysis, hyperglycemia correlated with age ($p<0.01$), a recent smoking habit ($p<0.01$), CPI ($p<0.01$), PD ($p<0.01$), and the number of present teeth ($p<0.01$) and unreplaced missing teeth ($p<0.01$). Midnight snacking was associated with MetS ($p=0.069$). The multivariate analysis revealed that hyperglycemia correlated with age (OR : 1.06, 95 % CI : 1.04-1.08, $p<0.001$) and a recent smoking habit (no vs yes, OR : 2.84, 95 % CI : 1.60-5.01, $p<0.001$). CPI tended to be associated with hyperglycemia (code 2 vs 3, OR : 1.52 95 % CI : 1.00-2.31, code 2 vs 4, OR : 1.29 95 % CI : 0.56-2.87, $p=0.07$). These results revealed that individuals with advanced age and a recent smoking habit were associated with hyperglycemia. It was also suggested that the presence of periodontal pockets tended to be associated with hyperglycemia.

G Relationship between dental conditions and renal function (Table 7)

In the present study, renal function was assessed in specific medical check-ups, and its relationship with dental conditions was also evaluated. Renal dysfunction correlated with sex ($p<0.01$), age ($p<0.01$), regular exercise ($p<0.05$), and oral hygiene ($p<0.01$). In the multivariate analysis, renal dysfunction correlated with sex (female vs male, OR : 1.66, 95 % CI : 1.07-2.59, $p<0.05$) and age (OR : 1.02, 95 % CI : 1.002-1.04, $p<0.05$), and tended to be associated with oral hygiene ($p=0.050$). These results revealed that male

Table 3 Association between obesity and independent variables

		Non-obese	Obese	Results of the univariate analysis		Results of a logistic regression analysis (p value)	
				p value	test name	p value	odds ratio (95 %CI)
Sex	Female (524)	466	58	<0.01	Chi-squared test	<0.01	1.00
	Male (461)	304	157				4.06 (2.90–5.74)
Age	Mean (SD)	59.2 (12.3)	60.0 (11.4)	NS	Wilcoxon rank-sum test	NS	
Recent smoking habit	No (925)	733	192	<0.01	Chi-squared test	NS	
	Yes (60)	37	23				
Alcohol intake	No (480)	388	92	<0.05	Chi-squared test	NS	
	Occasional (297)	231	66				
	Daily, light-moderate (171)	128	43				
	Daily, heavy (37)	23	14				
Midnight snacking	No (874)	687	187	NS	Chi-squared test	NS	
	Yes (111)	83	28				
Regular exercise	No (666)	510	156	0.079	Chi-squared test	<0.05	1.51 (1.06–2.16)
	Yes (319)	260	59				1.00
Oral hygiene	Good (589)	486	103	<0.01	Chi-squared test	NS	
	Fair (344)	246	98				
	Poor (51)	37	14				
	missing data (1)	1					
CPI	0 (321)	266	55	<0.05	Chi-squared test	<0.05	1.00
	1 (69)	54	15				1.34 (0.67–2.57)
	2 (388)	301	87				1.20 (0.81–1.78)
	3 (163)	114	49				1.70 (1.05–2.70)
	4 (29)	23	6				1.01 (0.35–2.56)
	missing data (15)	12	3				
Pocket depth	1–3 mm (778)	621	157	<0.05	Chi-squared test	NS	
	4–5 mm (163)	114	49				
	≥6 mm (29)	23	6				
	missing data (15)	12	3				
No. of present teeth	Mean (SD)	25.4 (5.4)	25.7 (5.0)	NS	Wilcoxon rank-sum test	NS	
No. of unreplaced missing teeth	Mean (SD)	0.5 (1.9)	0.5 (1.2)	<0.05	Wilcoxon rank-sum test	NS	

NS : Not significant

Table 4 Association between hypertension and independent variables

		Non-hypertensive	Hypertensive	Results of the univariate analysis		Results of a logistic regression analysis (p value)	
				p value	test name	p value	odds ratio
Sex	Female (524)	312	212	<0.05	Chi-squared test	NS	
	Male (461)	243	218				
Age	Mean (SD)	55.3 (13.0)	64.5 (8.3)	<0.01	Welch's t-test	<0.01	1.08 (1.07-1.10)
Recent smoking habit	No (925)	533	392	<0.01	Chi-squared test	<0.05	2.27 (1.16-4.16)
	Yes (60)	22	38				
Alcohol intake	No (480)	266	214	NS	Chi-squared test	NS	
	Occasional (297)	183	114				
	Daily, light-moderate (171)	88	83				
	Daily, heavy (37)	18	19				
Midnight snacking	No (874)	491	383	NS	Chi-squared test	NS	
	Yes (111)	64	47				
Regular exercise	No (666)	381	285	NS	Chi-squared test	NS	
	Yes (319)	174	145				
Oral hygiene	Good (589)	351	238	<0.01	Chi-squared test	NS	
	Fair (344)	185	159				
	Poor (51)	19	32				
	missing data (1)		1				
CPI	0 (321)	206	115	<0.01	Chi-squared test	<0.05	1.00
	1 (69)	41	28				1.02 (0.57-1.81)
	2 (388)	214	174				1.60 (1.14-2.26)
	3 (163)	80	83				1.29 (0.83-1.99)
	4 (29)	9	20				1.83 (0.77-4.64)
	missing data (15)	5	10				
Pocket depth	1-3 mm (778)	461	317	p <0.01	Chi-squared test	NS	
	4-5 mm (163)	80	83				
	≥6 mm (29)	9	20				
	missing data (15)	5	10				
No. of present teeth	Mean (SD)	25.5 (5.4)	25.8 (4.7)	NS	Wilcoxon rank-sum test	NS	
No. of unreplaced missing teeth	Mean (SD)	0.3 (0.9)	0.7 (2.4)	<0.01	Wilcoxon rank-sum test	<0.05	1.12 (1.003-1.26)

NS : Not significant

Table 5 Association between lipid abnormalities and independent variables

		No lipid abnormality	With lipid abnormalities	Results of the univariate analysis		Results of a logistic regression analysis (p value)	
				p value	test name	p value	odds ratio
Sex	Female (524)	372	152	<0.01	Chi-squared test	NS	
	Male (461)	285	176				
Age	Mean (SD)	57.7 (12.7)	62.6 (10.1)	<0.01	Welch's t-test	<0.001	1.04 (1.02-1.05)
Recent smoking habit	No (925)	631	294	<0.01	Chi-squared test	<0.001	2.90 (1.68-5.05)
	Yes (60)	26	34				
Alcohol intake	No (480)	306	174	<0.05	Chi-squared test	0.051	1.00
	Occasional (297)	216	81				0.69 (0.50-0.96)
	Daily, light-moderate (171)	114	57				0.80 (0.54-1.17)
	Daily, heavy (37)	21	16				1.16 (0.57-2.35)
Midnight snacking	No (874)	581	293	NS	Chi-squared test	NS	
	Yes (111)	76	35				
Regular exercise	No (666)	457	209	0.07	Chi-squared test	NS	
	Yes (319)	200	119				
Oral hygiene	Good (589)	406	183	NS	Chi-squared test	NS	
	Fair (344)	221	123				
	Poor (51)	30	21				
	missing data (1)		1				
CPI	0 (321)	210	111	<0.05	Chi-squared test	NS	
	1 (69)	51	18				
	2 (388)	270	118				
	3 (163)	106	57				
	4 (29)	13	16				
	missing data (15)	7	8				
Pocket depth	1-3 mm (778)	531	247	<0.05	Chi-squared test	NS	
	4-5 mm (163)	106	57				
	≥6 mm (29)	13	16				
	missing data (15)	7	8				
No. of present teeth	Mean (SD)	25.8 (5.3)	25.0 (5.3)	<0.01	Wilcoxon rank-sum test	NS	
No. of unreplaced missing teeth	Mean (SD)	0.4 (1.4)	0.7 (2.3)	<0.01	Wilcoxon rank-sum test	NS	

NS: Not significant

Table 6 Association between hyperglycemia and independent variables

		Non-hyperglycemic	Hyperglycemic	Results of the univariate analysis		Results of a logistic regression analysis (p value)	
				p value	test name	p value	odds ratio
Sex	Female (524)	389	135	NS	Chi-squared test	NS	
	Male (461)	322	139				
Age	Mean (SD)	57.4 (12.8)	64.5 (8.1)	<0.01	Welch's t-test	<0.001	1.06 (1.04-1.08)
Recent smoking habit	No (925)	679	246	<0.01	Chi-squared test	<0.001	2.84 (1.60-5.01)
	Yes (60)	32	28				
Alcohol intake	No (480)	345	135	NS	Chi-squared test	NS	
	Occasional (297)	215	82				
	Daily, light-moderate (171)	123	48				
	Daily, heavy (37)	28	9				
Midnight snacking	No (874)	623	251	0.069	Chi-squared test	NS	
	Yes (111)	88	23				
Regular exercise	No (666)	491	175	NS	Chi-squared test	NS	
	Yes (319)	220	99				
Oral hygiene	Good (589)	431	158	NS	Chi-squared test	NS	
	Fair (344)	245	99				
	Poor (51)	34	17				
	missing data (1)	1					
CPI	0 (321)	230	91	<0.01	Chi-squared test	0.07	
	1 (69)	49	20				
	2 (388)	302	86				1.00
	3 (163)	103	60				1.52 (1.00-2.31)
	4 (29)	18	11				1.29 (0.56-2.87)
	missing data (15)	9	6				
Pocket depth	1-3 mm (778)	581	197	<0.01	Chi-squared test	NS	
	4-5 mm (163)	103	60				
	≥6 mm (29)	18	11				
	missing data (15)	9	6				
No. of present teeth	Mean (SD)	25.9 (5.0)	24.4 (6.1)	<0.01	Wilcoxon rank-sum test	NS	
No. of unreplaced missing teeth	Mean (SD)	0.4 (1.7)	0.7 (2.0)	<0.01	Wilcoxon rank-sum test	NS	

NS : Not significant

Table 7 Association between renal function and independent variables

		Normal	Decreased renal function	Results of the univariate analysis		Results of a logistic regression analysis (p value)	
				p value	test name	p value	odds ratio
Sex	Female (524)	486	38	<0.01	Chi-squared test	<0.05	1.66 (1.07-2.59)
	Male (461)	401	60				
Age	Mean (SD)	59.0 (12.2)	62.6 (10.2)	<0.01	Welch's t-test	<0.05	1.02 (1.002-1.04)
Recent smoking habit	No (925)	831	94	NS	Chi-squared test	NS	
	Yes (60)	56	4				
Alcohol intake	No (480)	443	37	NS	Chi-squared test	NS	
	Occasional (297)	260	37				
	Daily, light-moderate (171)	151	20				
	Daily, heavy (37)	33	4				
Midnight snacking	No (874)	782	92	NS	Chi-squared test	NS	
	Yes (111)	105	6				
Regular exercise	No (666)	609	57	<0.05	Chi-squared test	NS	
	Yes (319)	278	41				
Oral hygiene	Good (589)	546	43	<0.01	Chi-squared test	0.050	1.00
	Fair (344)	295	49				1.75 (1.12-2.74)
	Poor (51)	45	6				1.36 (0.54-3.46)
	missing data (1)	1					
CPI	0 (321)	295	26	NS	Chi-squared test	NS	
	1 (69)	62	7				
	2 (388)	348	40				
	3 (163)	145	18				
	4 (29)	24	5				
	missing data (15)	13	2				
Pocket depth	1-3 mm (778)	705	73	NS	Chi-squared test	NS	
	4-5 mm (163)	145	18				
	≥6 mm (29)	24	5				
	missing data (15)	13	2				
No. of present teeth	Mean (SD)	25.5 (5.3)	25.7 (5.8)	NS	Wilcoxon rank-sum test	NS	
No. of unreplaced missing teeth	Mean (SD)	0.5 (1.8)	0.5 (1.3)	NS	Wilcoxon rank-sum test	NS	

NS: Not significant

gender and individuals of advanced age were associated with renal dysfunction. Poor oral hygiene had a tendency toward renal dysfunction.

Ⅳ Discussion

Periodontal conditions were previously reported to be closely associated with MetS. The number of positive MetS components correlated with gingivitis, even in participants aged between 12 and 18 years[15]. A meta-analysis revealed that individuals with MetS were nearly 2-fold more likely to have periodontitis than those without[13]. Japanese individuals with deep PD (≥6 mm) and severe CAL (≥6 mm) as well as those with moderate PD (4-5 mm) and moderate CAL (4-5 mm) were shown to be at a significantly increased risk of MetS[4]. Similarly, a higher CPI code was associated with the presence of a greater number of MetS components[11]. The prevalence of MetS was 18 % in individuals with no/mild periodontitis, whereas it was 37 % in those with severe periodontitis (classified by the clinical criteria of Page & Eke)[9]. However, in the present study, the multivariate analysis revealed no correlations between the positive number of MetS components and periodontal conditions. Oral health is influenced by diet, hygiene, smoking, alcohol intake, stress, and trauma[18]. MetS is also influenced by these risk factors. Many chronic diseases, including periodontitis, hypertension, and DM, are influenced by common risk factors[18]. In the present study, the assessment of correlation coefficients among independent valuables revealed that age and a recent smoking habit influenced MetS and dental conditions (CPI/PD, oral hygiene, and number of present or unreplaced missing teeth). These results suggest that age and smoking are confounding factors for periodontitis and MetS. MetS and periodontitis may be generated from common risk factors (such as age, smoking, and alcohol intake).

However, in the present study, periodontitis (high CPI code) correlated with some components of Mets, including obesity, hypertension, and hyperglycemia. These results suggest a possible relationship between periodontitis and any component of MetS. A cross-sectional study on adult Japanese male and female employees ranging in age between 20 and 59 years revealed that individual components of MetS, including obesity, hypertension, lipid abnormalities, and hyperglycemia, were associated with periodontal diseases[10]. Additionally, in a cohort study during a 4-year observation period, the presence of periodontal pockets was associated with the positive conversion of one or more MetS components[12]. Among MetS components, the positive conversion of blood pressure and the blood-lipid index correlated with the presence of periodontal pockets[12]. Furthermore, individuals with untreated MetS presented with markedly worse periodontal conditions than healthy participants. However, the prevention of periodontitis has been suggested to reduce the risk of MetS. According to a double-blinded randomized clinical study, periodontal therapy, including root planing + systemic antibiotics or plaque control + subgingival scaling, successfully decreased C-reactive protein levels in MetS patients[30]. The reduction of periodontal inflammation was reported to be the key in reducing systemic inflammation in patients with MetS[30]. Even supragingival plaque control was sufficiently effective to siginificantly improve periodontal inflammation and to reduce its impact on systemic inflammation as measured by CRP[30]. Since more frequent toothbrushing was related to a lower prevalence and incidence of MetS, more frequent toothbrushing may contribute to the prevention of MetS due to the inflammation/triglyceride pathway[31]. Therefore, collaborations between dentists and physicians are important. In addition, the specific health check-ups, including dental check-ups, were demonstrated to be effective for the early detection of periodontitis, a precursor of pre-MetS and MetS. Since the key concept underlying the integrated common risk approach is that the promotion of general health by controlling a small number of risk factors may have a major impact on a large number of diseases at a lower cost and greater efficacy and effectiveness than disease-specific approaches[32], the addition of dental check-ups to specific health check-ups may be effective for the early detection of individuals with pre-MetS and MetS.

With the inclusion of dental check-ups in specific health check-ups, dental interventions may reduce the risk of MetS. However, since the questionnaires of this study did not include the question whether individuals had received periodontal treatment/maintenance or not, the result of this question might have affected the outcomes of the study. The limitation of the present study was that since this was a cross-sectional study, the intervention effects of dental check-ups to reduce the risk of MetS were unclear. Furthermore, since most individuals who underwent specific health check-ups were aware of their health conditions, the frequency of medical care use in these individuals may affect investigations of medical expenditure. The dentist's calibrations of periodontal measurements might also affect the outcomes of the study. In this study, although periodontal measurements were determined by index teeth, the accuracy of measuring CPI was reported to vary with the dentist during the training process[33)34)]. Additionally, CPI was reported to vary between studies and such variation would affect the effect of each predictor on risk for periodontal diseases[35)]. Therefore, since the dental model was reported to be effective for periodontal pocket probing training and for the evaluation and standardization of the examiner's probing skill[35)], all the dentists who participated in this study were trained with dental models for dentist's calibration. According to WHO, although CPI is recommended for use as an indicator of early periodontitis in individuals of 35 and older as part of large community-based screening programs, the effects of risk factors on periodontitis measured with CPI in a large population-based survey were reported to be underestimated without correcting for measurement errors[36)]. Therefore, further studies are needed to investigate the efficacy of dental check-ups on the prevention of the progression of MetS based on a cohort study.

Ⅴ Conclusion

The aim of the present study was to investigate the relationship between periodontal disease and MetS with a combination of the specific health and dental check-ups based on a cross-sectional study. The results obtained suggest that periodontitis and Mets are generated from the same common risk factors including age, smoking, and alcohol intake. However, periodontitis was directly related to some MetS components (obesity, hypertension, and hyperglycemia). Since the key concept underlying the integrated common risk approach is the promotion of general health by controlling a small number of risk factors, the addition of dental check-ups to specific health check-ups is warranted.

Ⅵ Conflict of interest

The authors declare that they have no conflict of interest.

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