Abstract: Dental caries could be a risk factor for metabolic syndrome (MetS); however, there is limited evidence of such a relationship in the literature. This cross-sectional study investigated the relationships among dental caries experience, dietary habits, and MetS in Japanese adults. A total of 937 participants aged 40-74 years underwent a health check, including dental examination. Decayed, missing, and filled teeth (DMFT) were used as an index of caries experience. The mean DMFT score was 14, and 12% of the participants had MetS in this study. Multivariate logistic regression analyses showed that the prevalence of MetS was significantly related to DMFT (first vs. fourth quartile, odds ratio [OR] = 1.80; \( P < 0.05 \)). In addition, the OR of DMFT for MetS was found to be greater in each successively higher DMFT quartile. The prevalence of MetS was significantly related to daily coffee consumption (OR = 0.51, \( P < 0.01 \)), and the relationship between DMFT and MetS was noted after adjusting for daily coffee consumption. There appears to be a positive association between caries experience and MetS in Japanese adults. This relationship increased with the increase in DMFT regardless of dietary habits.

Introduction
Dental caries is an infectious microbial disease of the calcified tissues of the teeth and is recognized as the major cause of tooth loss in Japan (1). The prevalence of dental caries is associated with lifestyle-related factors, including dietary habits such as sugar consumption (2). Furthermore, recent studies suggest that dental caries is also associated with smoking (3) and tooth brushing (4) habits. Associations between dental caries and increases in body mass index (BMI) (5) and hemoglobin A1c have been reported in type 2 diabetes patients (6).

Metabolic syndrome (MetS), defined as a cluster of at least three of five metabolic abnormalities (abdominal obesity, hypertension, insulin resistance, and abnormal cholesterol or triglyceride levels), dramatically increases the risk of cardiovascular diseases (7,8). Previous studies have investigated the relationship between dental caries and MetS; for example, Cao et al. reported that the odds ratios (ORs) for MetS among middle-aged Chinese adults with two or more carious teeth and two or more decayed, missing, and filled teeth (DMFT) were 1.12 (95% confidence interval [CI], 1.14-1.74) and 1.09 (95% CI, 0.89-1.21), respectively, when compared with those without caries (9). Decayed teeth have also been found to be significantly related to the MetS components, hypertension, dyslipidemia, and hyperglycemia, with adjusted ORs of 1.22 (95% CI, 1.07-1.39), 1.18 (95% CI, 1.03-1.34), and 1.33 (95% CI, 1.13-1.56), respectively.

Keywords: dental caries; metabolic syndrome; dietary habits; cross-sectional study.
These findings suggest that dental caries could be a risk factor for MetS. However, owing to the limited availability of evidence of such a relationship, additional clinical studies are required. A previous study reported that eating habits were a common risk factor of MetS and dental caries (11). Therefore, it is feasible that the relationship between MetS and dental caries might be affected by dietary habits.

It was hypothesized that the prevalence of MetS would be higher among adults with greater caries experience (DMFT) than among those with less caries experience. Furthermore, this association might change according to their dietary habits. The purpose of this cross-sectional study was to investigate the relationships among caries experience, dietary habits, and MetS in Japanese adults.

Materials and Methods

Study population
The participants in this study consisted of 1,016 Japanese adults (age, 53 ± 8.6 years) who underwent oral health check-ups between January and December of 2016 at the Asahi University Hospital in Gifu, Japan. Seventy nine participants were excluded because of missing data. The study protocol was approved by the Ethics Committee of Asahi University (No. 27010). All participants provided written informed consent prior to participation in the study.

Medical examination
Height and body weight were measured using a body composition meter (Tanita, Tokyo, Japan). Waist circumference (WC) was measured, and BMI (weight in kilograms divided by the square of height in meters) was calculated. In addition, an automatic blood pressure monitor (Omron Healthcare, Kyoto, Japan) was used to measure systolic blood pressure (SBP) and diastolic blood pressure (DBP). Venous blood samples were collected following an overnight fast, and a simultaneous multi-item automatic analyzer (Siemens Healthineers Japan, Tokyo, Japan) was used to determine serum biochemical markers, total cholesterol, triglycerides, high-density lipoprotein (HDL) cholesterol, and low-density lipoprotein (LDL) cholesterol. Fasting blood glucose (FBG) was determined using a diabetes automatic analyzer (Kyowa Medex, Tokyo, Japan).

Definition of MetS
MetS was defined according to the recommendations of the Japanese Committee for the Diagnostic Criteria of Metabolic Syndrome (12,13). The presence of central obesity (WC ≥85 cm in males, ≥90 cm in females) was checked, along with two or more of the following risk factors: lipid abnormality (triglycerides ≥150 mg/dL and/ or HDL cholesterol <40 mg/dL or use of medications for dyslipidemia), high blood pressure (SBP ≥130 mmHg and/or DBP ≥85 mmHg or use of medications for hypertension), and hyperglycemia (fasting blood sugar ≥110 mg/dL or use of medications for diabetes).

Oral examination
Two dentists (T.O. and A.I.) performed oral examinations on the study participants. The number of teeth and DMFT index were recorded according to the World Health Organization criteria (14,15). Periodontal condition was assessed using the Community Periodontal Index (CPI) (16). In the current study, participants with a probing pocket depth of ≥4 mm in more than one tooth were diagnosed with periodontal disease (17). To check the intra- and inter-examiner agreement, counts of DMFT and CPI were recorded and repeated within a 2 week interval in 10 volunteers. Data were analyzed using the non-parametric kappa test and intra-class correlation. The kappa coefficients for intra- and inter-examiner and intra-class correlation coefficients were >0.8.

Questionnaire
Dietary habits were assessed by a self-administered food frequency questionnaire. The questionnaire provided three categories of response (rarely or never, occasionally, or every day) to describe the frequency of consumption of alcohol, beef or pork, chicken, fish, dairy products, eggs, bean products, confectionery or sweet snacks, vegetables, fruits, and coffee (17,18). Subsequently, the responses were consolidated into two categories: not every day and every day (<1 cup/day and ≥1 cup/day, respectively). The questionnaire also included gender, age, smoking (Brinkman index), regular exercise (apply/not apply), and tooth brushing frequency.

Statistical analysis
Chi-square or Mann-Whitney U tests were used to compare the participants with and without MetS. The participants were divided into four quartiles based on the DMFT (0-9, 10-13, 14-17, and 18-28), and Kruskal-Wallis test with post hoc Mann-Whitney U test and corrected Bonferroni methods were used to compare the prevalence of MetS among the participants across the four quartiles. Univariate and multivariate logistic regression analyses with stepwise method (backward selection approach) were performed with presence of MetS as the dependent variable. In the stepwise method, variables were removed from the model at P < 0.10 and
added to the model at \( P < 0.05 \). In the model for MetS, DMFT quartiles were included as the independent variable. Other independent variables were selected when the \( P \) value was <0.05 in the univariate model. \( P \) values less than 0.05 were considered as statistically significant in the logistic regression analyses.

Analyses were performed using a statistical package (IBM SPSS statistics version 24, IBM Japan, Tokyo, Japan).

**Results**

Table 1 presents the characteristics of the participants in this study. The overall prevalence of MetS was 12%. Significant differences between participants with and without MetS with respect to the consumption of dairy products were noted (\( P < 0.01 \)). Similarly, significant differences in gender, age, Brinkman Index, BMI, WC, SBP, DBP, serum FBG, triglycerides, HDL cholesterol, and CRP concentrations were noted between participants with and without MetS (\( P < 0.001 \)). Furthermore, significant differences in periodontitis status; DMFT; frequency of tooth brushing per day; and consumption of bean products, confectionery or sweet snacks, and coffee were observed between the participants with and without MetS (\( P < 0.05 \)).

Comparisons across DMFT quartile groups are shown in Table 2. Increase in age and decrease in the number of teeth present appeared to be associated with higher DMFT quartiles. Brinkman index, SBP, DBP, and triglyceride levels were significantly higher in participants belonging to the fourth DMFT quartile when compared with those in the other three quartiles (\( P < 0.05 \)).

### Table 1 Comparison of characteristics between participants with and without metabolic syndrome (n = 937)

| Variables                                      | All          | Without MetS (n = 827) | With MetS (n = 110) | \( P \) value |
|------------------------------------------------|--------------|------------------------|---------------------|--------------|
| Gender \(^a\)                                  | 608/329 (35%)| 506/321 (39%)          | 102/8 (7.3%)        | <0.001       |
| Age, years                                     | 53 (45, 59)  | 52 (45, 59)            | 56 (52, 61)         | <0.001       |
| Regular drinking habits \(^b\)                 | 760/117 (19%)| 676/151 (18%)          | 84/26 (24%)         | 0.19         |
| Brinkman Index, n                              | 0 (0, 348)   | 0 (0, 300)             | 310 (0, 600)        | <0.001       |
| Regular exercise habits \(^c\)                 | 738/199 (21%)| 650/177 (21%)          | 88/22 (20%)         | 0.81         |
| BMI, kg/m\(^2\)                                | 22.7 (20.6, 24.9) | 22.3 (20.4, 24.1)   | 26.5 (25.3, 28.0)  | <0.001       |
| WC, cm                                         | 80 (74, 86)  | 79 (73, 83)            | 90 (87, 94)         | <0.001       |
| SBP, mmHg                                      | 119 (109, 129)| 117 (107, 127)        | 132 (125, 137)      | <0.001       |
| DBP, mmHg                                      | 73 (66, 81)  | 72 (65, 79)            | 83 (77, 88)         | <0.001       |
| FGB, mg/dL                                     | 99 (93,106)  | 98 (92, 104)           | 115 (103, 127)      | <0.001       |
| Total cholesterol, mg/dL                       | 205 (183, 226)| 205 (183, 227)        | 201 (177, 222)      | 0.66         |
| Triglyceride, mg/dL                            | 68 (50, 102) | 64 (48, 93)            | 117 (78, 172)       | <0.001       |
| HDL, mg/dL                                     | 62 (51, 75)  | 65 (52, 76)            | 51 (43, 59)         | <0.001       |
| LDL, mg/dL                                     | 112 (95, 131)| 112 (95, 130)          | 111 (94,131)        | 0.77         |
| CRP, mg/dL                                     | 0.04 (0.02, 0.08) | 0.04 (0.01, 0.07)    | 0.09 (0.04, 0.20)   | <0.001       |
| Present teeth (excluded third molar), n        | 28 (26, 28)  | 28 (26, 28)            | 27 (25, 28)         | 0.13         |
| Periodontitis (PPD ≥4 mm) \(^d\)               | 205/732 (78%)| 190/637 (77%)          | 15/95 (86%)         | <0.05        |
| DMFT, n                                        | 14 (9, 18)   | 14 (9, 18)             | 16 (11, 20)         | <0.05        |
| Frequency of tooth brushing per day, n         | 2 (2, 3)     | 2 (2, 3)               | 2 (1, 2)            | <0.05        |
| Frequency of dietary consumption \(^e\)        |             |                        |                     |              |
| Beef or Pork                                    | 740/197 (21%)| 646/181 (22%)          | 94/16 (15%)         | 0.08         |
| Chicken                                        | 834/103 (11%)| 730/97 (12%)           | 104/6 (5.5%)        | 0.05         |
| Fish                                           | 828/109 (12%)| 730/97 (12%)           | 98/12 (11%)         | 0.88         |
| Dairy products                                  | 437/500 (53%)| 371/456 (55%)          | 66/44 (40%)         | <0.01        |
| Eggs                                           | 577/360 (38%)| 501/326 (39%)          | 76/34 (31%)         | 0.10         |
| Bean products                                   | 650/287 (31%)| 563/264 (32%)          | 87/23 (21%)         | <0.05        |
| Confectionery or sweet snack                    | 607/330 (35%)| 526/301 (36%)          | 81/29 (26%)         | <0.05        |
| Vegetables                                     | 253/684 (73%)| 215/612 (74%)          | 38/72 (66%)         | 0.07         |
| Fruits                                         | 665/272 (29%)| 578/249 (30%)          | 87/23 (21%)         | 0.06         |
| Coffee                                         | 194/743 (79%)| 163/664 (80%)          | 31/79 (72%)         | <0.05        |

Continuous variables are expressed as median (first quartile, third quartile) deviation.

\(^a\): Chi-square test (Direct method of Fisher) or Mann-Whitney U test.

\(^b\): male/female (percentage of female); \(^c\): not every day/every day (percentage of every day); \(^d\): not apply/apply (percentage of apply); \(^e\): absence/presence (percentage of presence).

MetS: metabolic syndrome; BMI: body mass index; WC: waist circumference; SBP: systolic blood pressure; DBP: diastolic blood pressure; FGB: fasting blood glucose; HDL: high-density lipoprotein; LDL: low-density lipoprotein; CRP: C-reactive protein; PPD: probing pocket depth; DMFT: decayed teeth, missing teeth because of caries, and filled teeth.
Table 2 Comparison of characteristics among participants in each DMFT quartile group (n = 937)

| Variables | All | First quartile (n = 236) | Second quartile (n = 216) | Third quartile (n = 229) | Fourth quartile (n = 256) | P value
|-----------|-----|--------------------------|--------------------------|--------------------------|--------------------------|-------|
| Gender† | 608/329 (35%) | 166/70 (30%) | 135/81 (38%) | 130/99 (43%) | 177/79 (31%) | <0.01 |
| Age, years | 53 (45, 59) | 48 (43, 56) | 52 (44, 58) | 53 (47, 58) | 57 (52, 62) | <0.001 |
| Regular drinking habits‡ | 760/117 (19%) | 196/40 (17%) | 178/38 (18%) | 183/46 (20%) | 203/53 (21%) | 0.66 |
| Brinkman Index, n | 0 (0, 348) | 0 (0, 215) | 0 (0, 300) | 0 (0, 340) | 35 (0, 500) | <0.01 |
| Regular exercise habits‡ | 738/199 (21%) | 188/48 (20%) | 171/45 (21%) | 181/48 (21%) | 198/58 (23%) | 0.93 |
| BMI, kg/m² | 22.7 (20.6, 24.9) | 22.7 (20.8, 24.7) | 22.7 (20.7, 24.8) | 22.4 (20.2, 24.7) | 22.9 (20.8, 25.5) | 0.14 |
| WC, cm | 80 (74, 86) | 80 (75, 85) | 79 (73, 86) | 79 (73, 85) | 81 (75, 87) | 0.07 |
| SBP, mmHg | 119 (109, 129) | 119 (107, 129) | 117 (107, 127) | 117 (107, 127) | 122 (112, 132) | <0.01 |
| DBP, mmHg | 73 (66, 81) | 74 (64, 81) | 72 (66, 79) | 71 (65, 81) | 75 (67, 83) | <0.05 |
| TC, mg/dL | 205 (183, 226) | 201 (183, 227) | 206 (183, 227) | 202 (177, 224) | 207 (185, 229) | 0.45 |
| TG, mg/dL | 68 (50, 102) | 64 (47, 90) | 67 (47, 105) | 72 (54, 112) | 75 (67, 83) | <0.05 |
| HDL, mg/dL | 99 (93, 106) | 99 (92, 106) | 98 (93, 104) | 99 (92, 102) | 100 (95, 107) | 0.24 |
| LDL, mg/dL | 112 (95, 131) | 109 (95, 135) | 114 (95, 135) | 109 (94, 128) | 114 (97, 131) | 0.27 |
| CRP, mg/dL | 0.04 (0.02, 0.08) | 0.04 (0.02, 0.08) | 0.04 (0.02, 0.08) | 0.04 (0.02, 0.09) | 0.04 (0.01, 0.08) | 0.95 |

Continuous variables are expressed as median (first quartile, third quartile) deviation.

a: DMFT quartile groups: the range of DMFT of first quartile groups from 0 to 9; second quartile groups from 10 to 13; third quartile groups from 14 to 17; fourth quartile groups from 18 to 28.
b: Chi-square test (Direct method of Fisher) or Kruskal-Wallis test.
c: male/female (percentage of female); d: not every day/every day (percentage of every day); e: not apply/apply (percentage of apply); f: absence/presence (percentage of presence).

*: P < 0.05 compared with DMFT first quartile groups with Kruskal-Wallis test post hoc Mann-Whitney U test (corrected by Bonferroni methods).
†: P < 0.05 compared with DMFT second quartile groups with Kruskal-Wallis test post hoc Mann-Whitney U test (corrected by Bonferroni methods).
‡: P < 0.05 compared with DMFT third quartile groups with Kruskal-Wallis test post hoc Mann-Whitney U test (corrected by Bonferroni methods).

Table 3 shows the results of the univariate logistic regression analysis with MetS prevalence as the dependent variable. The prevalence of MetS was significantly correlated with the frequency of tooth brushing and consumption of dairy products, bean products, confectionery or sweet snack, fruits, and coffee (P < 0.05); in addition, significant correlations were noted between MetS and gender, age, Brinkman Index, presence of periodontitis, number of teeth present, and DMFT quartiles (P < 0.05).

Table 4 shows the results of the multivariate logistic regression analysis with MetS prevalence as the dependent variable. It was found that after adjusting for gender, age, regular drinking habits, Brinkman Index, frequency of dietary habits (including beef or pork, chicken, dairy products, eggs, bean products, confectionery or sweet snack, vegetables, fruits, and coffee), frequency of tooth brushing, presence of periodontitis, number of
Table 3  Factors associated with MetS: univariate logistic regression analysis

| Variables                        | Crude odds ratio | 95% Confidence level | P value |
|----------------------------------|------------------|-----------------------|---------|
| Gender a                         | 0.12             | 0.06-0.26             | <0.001  |
| Age b                            | 1.04             | 1.01-1.06             | <0.01   |
| Regular drinking habits c        | 1.39             | 0.86-2.23             | 0.18    |
| Brinkman Index b                 | 1.002            | 1.001-1.002           | <0.001  |
| Regular exercise habits d        | 0.92             | 0.56-1.51             | 0.74    |
| Frequency of dietary consumption c|                  |                       |         |
| Beef or pork                     | 0.61             | 0.35-1.06             | 0.08    |
| Chicken                          | 0.43             | 0.19-1.02             | 0.05    |
| Fish                             | 0.92             | 0.49-1.74             | 0.80    |
| Dairy products                   | 0.54             | 0.36-0.81             | <0.01   |
| Eggs                             | 0.69             | 0.45-1.06             | 0.09    |
| Bean products                    | 0.56             | 0.35-0.91             | <0.05   |
| Confectionery or sweets snack    | 0.63             | 0.40-0.98             | <0.05   |
| Vegetables                       | 0.67             | 0.44-1.02             | 0.06    |
| Fruits                           | 0.61             | 0.38-0.99             | <0.05   |
| Coffee                           | 0.63             | 0.40-0.98             | <0.05   |
| Frequency of tooth brushing per day b| 0.58     | 0.42-0.79             | <0.001  |
| Periodontitis (PPD >4 mm) e      | 1.89             | 1.07-3.33             | <0.05   |
| Present teeth (excluded third molar) b| 0.94     | 0.88-0.99             | <0.05   |
| DMFT quartile groups f           | 1.28             | 1.07-1.54             | <0.01   |

*a*: male/female (female), *b*: continuous variable, *c*: not every day/every day (every day), *d*: not apply/apply (apply), *e*: absence/presence (presence), *f*: the range of DMFT of the first quartile groups from 0 to 9; second quartile groups from 10 to 13; third quartile groups from 14 to 17; fourth quartile groups from 18 to 28.

MetS: metabolic syndrome; PPD: probing pocket depth; DMFT: decayed teeth, missing teeth because of caries, and filled teeth.

Table 4 Factors associated with metabolic syndrome: multivariate logistic regression analysis with stepwise method by backward selection approach

| Covariate                        | Adjusted odds ratio | 95% Confidence level | P value |
|----------------------------------|---------------------|----------------------|---------|
| Gender, (female)                 | 0.16                | 0.08-0.35            | <0.001  |
| Brinkman Index                   | 1.001               | 1.000-1.002          | <0.01   |
| Frequency of coffee consumption, (every day) | 0.51             | 0.32-0.83            | <0.01   |
| DMFT quartile groups a           |                     |                      |         |
| First quartile vs. Second quartile| 0.99                | 0.50-1.93            | 0.97    |
| First quartile vs. Third quartile | 1.56                | 0.84-2.89            | 0.16    |
| First quartile vs. Fourth quartile| 1.80                | 1.01-3.21            | <0.05   |

The statistical analysis for the adjusted odds ratio carried out multivariate logistic regression analysis with stepwise method by backward selection approach that adjusted by gender, age, Brinkman Index, frequency of dietary consumption (dairy products, bean products, confectionery or sweet snack, fruits, and coffee), frequency of tooth brushing per day, periodontitis, present teeth, and DMFT quartile groups. In addition, in this stepwise method, variables were removed from the model with P < 0.10 and variables were added to the model at P < 0.05.

*a*: DMFT quartile groups: the range of DMFT of first quartile groups from 0 to 9; second quartile groups from 10 to 13; third quartile groups from 14 to 17; fourth quartile groups from 18 to 28.

DMFT: decayed teeth, missing teeth because of caries, and filled teeth.

den present, and DMFT quartiles, the MetS prevalence was significantly related to gender (female, OR = 0.16; P < 0.001), Brinkman Index (OR = 1.001; P < 0.01), frequency of coffee consumption (every day, OR = 0.51; P < 0.01), and DMFT (first vs. fourth quartile, OR = 1.80; P < 0.05).

**Discussion**

This cross-sectional study investigated the relationship between DMFT and MetS in Japanese adults who received oral health checks. Participants with MetS had higher DMFT indices than those without MetS. In the logistic regression analyses, after adjusting for demographic, dietary, oral health, and other lifestyle factors, the OR of MetS increased with successively higher quartiles of DMFT. These results suggest that caries experience is positively associated with the presence of MetS in adults.

A previous study on the relationship between dental caries and MetS among urban Chinese middle-aged adults reported a higher prevalence of MetS in those with severe caries when compared with those with mild or no caries (9). In another study, the presence of decayed teeth was
thought to be directly related to MetS in a middle-aged Japanese male adult population (10). These observations are consistent with the hypothesis that dental caries and MetS are positively associated.

Infection by mutans streptococci is a known cause of dental caries (19). Recent studies have shown that mutans streptococci can be detected in cardiovascular specimens (20,21); furthermore, it has been demonstrated that mutans streptococci induce the production of inflammatory cytokines, interleukin (IL)-6, and IL-8, by endothelial cells in the invaded and infected human vascular wall (22). Thus, increased production of inflammatory cytokines has been shown to cause obesity and MetS (23). Seeding of the vascular system with mutans streptococci originating from dental caries lesions could initiate the production of inflammatory cytokines in the vascular walls, thus promoting conditions that would increase the risk of MetS. However, further studies are needed to clarify these proposed mechanisms.

Among the dietary products consumed, only coffee consumption showed a significantly negative association with MetS in the present study, indicating that daily consumption of coffee might reduce the risk of MetS. The chlorogenic acid present in coffee exerts anti-inflammatory effects (24) and may prove beneficial in reducing the risk of MetS, which is known to be associated with low-grade systemic inflammation (25).

In the present study, it was hypothesized that the association between DMFT and MetS might change on the basis of the dietary habits. However, the present analyses did not support this hypothesis, indicating that dietary habits may have little effect on the association between DMFT and MetS. In this study, the association between DMFT and MetS increased with the increase in DMFT quartile, implying that the amount of caries experience is a helpful indicator to see through the odds ratios of MetS. The effects of dietary habits on DMFT increase are affected by other factors; for instance, it is known that daily use of fluoride toothpaste reduces the longitudinal association between amount of sugar intake and dental caries (26). Similarly, other factors (e.g., use of fluoride toothpaste) can inhibit the association between dietary habits and DMFT, thereby weakening the effects of dietary habits on the association between DMFT and MetS.

Increasing evidence suggests a positive association between periodontitis and MetS (27,28). In the current study, no such relationship between periodontitis and MetS was noted. This may be attributed to the high prevalence of periodontitis in this study (76%); due to inadequate contrast, an association between periodontitis and MetS, if present, may have failed to achieve statistical significance.

The prevalence of MetS in the present study was 9.8%, which is much lower than that reported in the 2015 National Health and Nutrition Survey in Japanese adults (18.0%). Moreover, the average DMFT in the current study was 12.6 as compared with 16.9 in the 2017 Survey of Dental Disease. These disparities indicate that the prevalence of both MetS and DMFT in this study population were lower than those reported in the Japanese population. This is likely related to participants of this study being health-conscious subjects who sought regular elective health check-ups. Thus, the findings of this study may not be representative of the general population in Japan.

This study has other limitations as well. First, the sociological factors were not recorded, which could have an influence on dental caries and MetS (29-31). Second, the present study was a cross-sectional study, so causal relationships could not be detected or implied. Additional longitudinal studies will be needed to further elucidate the connections between MetS and DMFT.

In conclusion, there appears to be a positive association between caries experience and MetS in Japanese adults. This relationship was stronger in those with higher DMFT regardless of the dietary habits.

Acknowledgments
The authors thank dental hygienist Ms. Takada for her technical support.

Conflict of interest
None declared.

References
1. Aida J, Ando Y, Akhter R, Aoyama H, Masui M, Morita M (2006) Reasons for permanent tooth extractions in Japan. J Epidemiol 16, 214-219.
2. Peres MA, Sheiham A, Liu P, Demarco FF, Silva AE, Assunção MC et al. (2016) Sugar consumption and changes in dental caries from childhood to adolescence. J Dent Res 95, 388-394.
3. Vellappally S, Fiala Z, Smejkalová J, Jacob V, Shriharsha P (2007) Influence of tobacco use in dental caries development. Cent Eur J Public Health 15, 116-121.
4. Kumar S, Tadakamadla J, Johnson NW (2016) Effect of toothbrushing frequency on incidence and increment of dental caries: a systematic review and meta-analysis. J Dent Res 95, 1230-1236.
5. Alswat K, Mohamed WS, Wahab MA, Aboelil AA (2016) The association between body mass index and dental caries: cross-sectional study. J Clin Med Res 8, 147-152.
6. Yonekura S, Usui M, Murano S (2017) Association between numbers of decayed teeth and HbA1c in Japanese patients with type 2 diabetes mellitus. Ups J Med Sci 122, 108-113.
7. Santilli F, D’Ardes D, Guagnano MT, Davi G (2017) Metabolic syndrome: sex-related cardiovascular risk and therapeutic approach. Curr Med Chem 24, 2602-2627.
8. Saklayen MG (2018) The global epidemic of the metabolic syndrome. Curr Hypertens Rep 20, 12.
9. Cao X, Wang D, Zhou J, Yuan H, Chen Z (2017) Detection of cariogenic Streptococcus mutans, caries and simulation models. Nutrients 8, 114.
10. Kunitomo M, Ekuni D, Mizutani S, Tomofuji T, Irie K, Azuma T et al. (2016) Association between knowledge about dental caries and metabolic syndrome among 13 998 middle-aged urban Chinese. J Diabetes 9, 378-385.
11. Ojima M, Amano A, Kurata S (2015) Relationship between decayed teeth and metabolic syndrome: data from 4716 middle-aged male Japanese employees. J Epidemiol 25, 204-211.
12. Hattori T, Konno S, Munakata M (2017) Gender differences in lifestyle factors associated with metabolic syndrome and preliminary metabolic syndrome in the general population: the Watari study. Intern Med 56, 2253-2259.
13. Hashimoto Y, Hamaguchi M, Fukuda T, Obora A, Kojima T, Fukui M (2017) Weight gain since age of 20 as risk of metabolic syndrome even in non-overweight individuals. Endocrine 58, 253-261.
14. Kunitomo M, Ekuni D, Mizutani S, Tomofuji T, Irie K, Azuma T et al. (2016) Association between knowledge about comprehensive food education and increase in dental caries in Japanese university students: a prospective cohort study. Nutrients 8, 114.
15. Drachev SN, Brem T, Trovik TA (2017) Dental caries experience and determinants in young adults of the Northern State Medical University, Arkhangelsk, North-West Russia: a cross-sectional study. BMC Oral Health 17, 136.
16. Song IS, Han K, Park YM, Ji S, Jun SH, Ryu JJ et al. (2016) Severe periodontitis is associated with insulin resistance in non-abdominal obese adults. J Clin Endocrinol Metab 101, 4251-4259.
17. Iwasaki T, Hirose A, Azuma T, Ohashi T, Watanabe K, Obora A et al. (2018) Correlation between ultrasound-diagnosed non-alcoholic fatty liver and periodontal condition in a cross-sectional study in Japan. Sci Rep 8, 7496.
18. Hurst Y, Fukuda H (2018) Effects of changes in eating speed on obesity in patients with diabetes: a secondary analysis of longitudinal health check-up data. BMJ Open 8, e019589.
19. Forsten SD, Björklund M, Owelhand AC (2010) Streptococcus mutans, caries and simulation models. Nutrients 2, 290-298.
20. Nakano K, Inaba H, Nomura R, Nemoto H, Takeda M, Yoshioka H et al. (2006) Detection of cariogenic Streptococcus mutans in extirpated heart valve and atheromatous plaque specimens. J Clin Microbiol 44, 3313-3317.
21. Nakano K, Nemoto H, Nomura R, Inaba H, Yoshioka H, Taniguchi K et al. (2009) Detection of oral bacteria in cardiovascular specimens. Oral Microbiol Immunol 24, 64-68.
22. Nagata E, de Toledo A, Oho T (2011) Invasion of human aortic endothelial cells by oral viridans group streptococci and induction of inflammatory cytokine production. Mol Oral Microbiol 26, 78-88.
23. Furukawa S, Fujita T, Shimabukuro M, Iwaki M, Yamada Y, Nakajima Y et al. (2004) Increased oxidative stress in obesity and its impact on metabolic syndrome. J Clin Invest 114, 1752-1761.
24. dos Santos MD, Almeida MC, Lopes NP, de Souza GE (2006) Evaluation of the anti-inflammatory, analgesic and antipyretic activities of the natural polyphenol chlorogenic acid. Biol Pharm Bull 29, 2236-2240.
25. Esser N, Legrand-Poels S, Piette J, Scheen AJ, Paquot N (2014) Inflammation as a link between obesity, metabolic syndrome and type 2 diabetes. Diabetes Res Clin Pract 105, 141-150.
26. Bernabé E, Vehkalahti MM, Sheiham A, Lundqvist A, Suominen AL (2016) The shape of the dose-response relationship between sugars and caries in adults. J Dent Res 95, 167-172.
27. Watanabe K, Cho YD (2014) Periodontal disease and metabolic syndrome: a qualitative critical review of their association. Arch Oral Biol 59, 855-870.
28. Jaramillo A, Contreras A, Lafaurie GI, Duque A, Ardila CM, Duarte S et al. (2017) Association of metabolic syndrome and chronic periodontitis in Colombians. Clin Oral Investig 21, 1537-1544.
29. Lin C, Nguyen T, Choue R, Wang Y (2012) Sociodemographic disparities in the composition of metabolic syndrome components among adults in South Korea. Diabetes Care 35, 2028-2035.
30. Yoshino K, Suzuki S, Ishizuka Y, Takayanagi A, Sugihara N, Kamiyo H (2017) Relationship between amount of overtime work and untreated decayed teeth in male financial workers admitted to Osaka Socio-Medical Center in Japan. Int Dent J 59, 96-102.
31. Lim H, Nguyen T, Choue R, Wang Y (2012) Sociodemographic disparities in the composition of metabolic syndrome components among adults in South Korea. Diabetes Care 35, 2028-2035.

Supplementary file
Supplementary table: Factors associated with MetS showing the stepwise process of multivariate stepwise logistic regression analysis with backward method. Please find the supplementary file; doi: 10.2334/josnusd.18-0153