ORIGINAL ARTICLE

Metabolic syndrome and periodontitis among adults: The 2018 Indonesia National Health Survey

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Abstract

Aim: This study aimed to examine the association between metabolic syndrome (MetS), its components, and periodontitis among Indonesian adults.

Materials and Methods: Cross-sectional data from the 2018 Indonesia National Health Survey (Riskesdas) was analysed. The sample included dentate individuals aged 35 years or older for whom complete information was available on components of MetS and periodontitis, including bleeding on probing (BOP) ($N = 13,356$), pocket depth (PD) ($N = 13,273$), and clinical attachment loss (CAL) ($N = 13,000$). Rate ratios (RRs) and 95% confidence intervals (CIs) were estimated with negative binomial regression models.

Results: The prevalence of MetS was 41.0%. The prevalence of individuals having at least one tooth with BOP, one tooth with PD ≥4 mm, or one sextant with CAL ≥4 mm was 74.9%, 40.7%, and 40.6%, respectively. No associations were observed between MetS and BOP, PD, or CAL, but hyperglycaemia was constantly positively associated with BOP (RR = 1.06; 95% CI 1.01–1.11), PD (RR = 1.13; 95% CI 1.03–1.23), and CAL (RR = 1.15; 95% CI 1.08–1.23).

Conclusions: Our findings support the potential influence of hyperglycaemia on periodontitis. Incorporating oral disease prevention strategies into the management of systemic diseases could be beneficial for reducing the burden of these diseases in Indonesia.

KEYWORDS
dental health surveys, hyperglycaemia, metabolic syndrome, periodontitis

Clinical Relevance

Scientific rationale for study: It remains unclear whether it is the presence of metabolic syndrome (MetS) or the sum of its components that have an additive effect on periodontitis. These associations are rarely investigated in Southeast Asian populations.
Principal findings: No association between MetS and bleeding on probing (BOP), pocket depth (PD), or clinical attachment loss (CAL) was observed. However, hyperglycaemia was positively associated with BOP, PD, and CAL.

Practical implications: Individuals with hyperglycaemia should be checked for periodontal diseases. Incorporating oral disease prevention strategies into the management of systemic diseases might reduce the burden of those diseases.

1 | INTRODUCTION

Periodontal diseases cause an inflammatory reaction that affects the periodontal tissues and represent a significant public health challenge (Petersen & Baehni, 2012; Huang & Gibson, 2014). The global prevalence of severe periodontitis in 2010 was 10.8%; the codition affected 743 million people worldwide and was the sixth most common disease globally (Kassebaum et al., 2014). The global burden of periodontal diseases rose by 25.8% between 2006 and 2016 (Vos et al., 2017). In Indonesia, the estimated prevalence of severe periodontitis was higher than the global mean, with the age-standardized prevalence and incidence rates of 17% and 747 per 100,000 person-years, respectively, in 2010 (Kassebaum et al., 2014). Periodontal diseases significantly impact an individual's oral, general health, and quality of life. They are the primary cause of tooth loss and are linked to non-communicable diseases (NCDs) (FDI World Dental Federation, 2019).

Metabolic syndrome (MetS), which is currently becoming a global epidemic (Saklayen, 2018), is among the NCDs known to be associated with periodontal diseases (Nibali et al., 2013). The term MetS was first coined by Gerald Reaven (Reaven, 1988); the condition is also known as syndrome X or insulin resistance syndrome. It is defined as a cluster of factors—hypertension, dyslipidaemia, insulin resistance, and central obesity—that increase the risk for cardiovascular disease and type 2 diabetes mellitus (Alberti et al., 2009). MetS is suggested to influence periodontitis through a common mechanism of oxidative stress (Marchetti et al., 2012). Both MetS and periodontitis elevate the serum levels of oxidative damage products, creating a pro-inflammatory state (Bullon et al., 2009).

Although previous studies have reported an association between MetS and periodontitis, it remains unclear whether it is the presence of MetS or the sum of its components that has an additive effect on periodontitis (Nibali et al., 2013; Lamster & Pagan, 2017). The magnitude of the association between MetS and periodontal diseases might also vary depending on the study population or ethnicity (Gobin et al., 2020). Evidence from Southeast Asian populations is still scarce. It has been suggested that Asians may have different metabolic characteristics from Caucasians with the same body mass index, including increased body fat percentages, abdominal and visceral fat deposition, and reduced muscle mass and connective tissue (Izumida et al., 2019). Furthermore, there is a dearth of studies reporting the periodontal clinical conditions of a national sample of Indonesian adults.

The aim of this study was to evaluate the association between MetS and its components and periodontal diseases among Indonesian adults. We hypothesized that MetS was associated with periodontal diseases.

2 | MATERIALS AND METHODS

This study was reported following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cross-sectional studies (von Elm et al., 2007).

2.1 | Data source

This study was a secondary data analysis of the 2018 Indonesia National Health Survey (Riset Kesehatan Dasar/Riskesdas), which is the latest version of the main national health survey in Indonesia. This cross-sectional survey used a two-stage sampling design, targeting 25,000 households for biomedical and dental examinations. The first stage was to systematically select 2500 census blocks across 26 provinces by considering the distribution of samples in each province and stratum at the district/city level. The next stage was to select 10 households per census block. All individuals in the selected households were included as samples. The implementation of the 2018 Riskesdas was approved by the Health Research Ethics Commission (Komisi Etik Penelitian Kesehatan/KEPK) of the National Institute of Health Research and Development (Balitbangkes), Ministry of Health, Indonesia (No. LB.02.01/2/KE.267/2017). Details of the survey methodology and sampling procedure have been described elsewhere (Badan Penelitian dan Pengembangan Kesehatan, 2019; Dany et al., 2020).

2.2 | Study samples

A subset of the data on 18,370 non-pregnant adults aged ≥35 years who underwent physical, biomedical, and oral health examinations was obtained with permission from the National Institute of Health Research and Development, Ministry of Health, Indonesia. Participants who were edentulous (*n* = 298), had all teeth excluded or not recorded from periodontal examination (*n* = 247), had insufficient diagnostic information on hypertension and diabetes (*n* = 4322), or had missing data on relevant confounders (*n* = 144) were excluded from our study. Of the 13,359, there were 3 missing values for bleeding on probing (BOP) and 86 for pocket depth (PD), leaving the final samples for the outcome of the number of teeth with BOP 13,356 and the number of teeth with PD 13,273. Nearly 359 had all six sextants excluded or not recorded from the clinical attachment loss (CAL) examination, leaving the final samples for the outcome of the number of sextants with CAL 13,000.

2.3 | Measurements

2.3.1 | Outcome variables

The outcome variables related to periodontitis were the number of teeth with BOP, the number of teeth with PD, and the number of sextants with CAL. Clinical oral examination was performed by trained and calibrated dentists at the study site, following the World Health Organisation (WHO) Oral Health Surveys guidelines (Badan Penelitian dan Pengembangan Kesehatan, 2019). The examinations for BOP and PD were carried out on all present teeth, including third molars. For each tooth, the status of BOP was recorded as 0 (no bleeding), 1 (bleeding), 9 (tooth excluded), or X (tooth not present), and the status of PD was recorded as 0 (0–3 mm), 1 (4–5 mm), 2 (6–8 mm), 9 (tooth excluded), or X (tooth not present). We classified a tooth as having PD if it was scored 1 or 2. Loss of attachment was measured only on the index teeth (17/16, 11, 26/27, 36/37, 31, 47/46) and was recorded as 0 (0–3 mm), 1 (4–5 mm), 2 (6–8 mm), 3 (9–11 mm), 4 (≥12 mm), X (excluded sextant), or 9 (not recorded) (World Health Organisation, 2013; Badan Penelitian dan Pengembangan Kesehatan, 2019). We classified a sextant as having CAL if it was scored 1, 2, 3, or 4.

2.3.2 | Metabolic syndrome

MetS was defined according to the Joint Interim Statement (JIS), using the waist circumference (WC) thresholds for Asian ethnicity (Alberti et al., 2009). The diagnosis of MetS was based on the presence of three of the following five: WC ≥90 cm in men and ≥80 cm in women; triglycerides (TG) ≥150 mg/dl; high-density lipoprotein cholesterol (HDL-C) <40 mg/dl in men and <50 mg/dl in women; systolic blood pressure ≥130 mmHg and/or diastolic blood pressure ≥85 mmHg or previously diagnosed hypertension or taking antihypertensive medications; fasting plasma glucose ≥100 mg/dl or diabetes. Having diabetes was defined as the presence of any of the following: previously diagnosed diabetes, post-load 2-h plasma glucose measurement ≥200 mg/dl, or random plasma glucose measurement ≥200 mg/dl with classic signs of hyperglycaemia (polyuria, polydipsia, weight loss, and polyphagia). Diagnostic criteria for elevated TG and reduced HDL-C were based solely on biochemical measurements, as the survey did not collect data related to medications used for treating these conditions.

2.3.3 | Confounders

Socio-demographic variables included age, gender, residential location, education, and occupation. Residential location was classified into urban and rural. Educational attainment was classified into elementary school or below, junior and senior high school, and higher education. Occupation was classified as non-manual work (private or government employees, entrepreneurs), manual work (farmers, fishermen, labourers, drivers, domestic helpers), or others (unemployed individuals, students, others).

Lifestyle variables included smoking and chewing tobacco. Smoking status was determined by asking individuals if they had ever smoked cigarettes, and whether they had smoked in the past month. Similar questions were asked for tobacco chewing. Based on the answers, smoking and chewing tobacco status were categorized into never, past, and current.

Oral health behaviours included tooth-brushing habits and dental visits. Tooth-brushing habits were measured by asking individuals if they brushed their teeth daily. Those answering "yes" were further asked to indicate whether they brushed at the following times: before breakfast, after breakfast, after lunch, during their morning shower, during their evening shower, and before bedtime. The answers of "yes" to after breakfast and before bedtime were considered to be correct (Melo et al., 2021). Based on the responses to these questions, tooth-brushing behaviours were categorized into the following three groups: not brushing daily, brushing daily but at the incorrect time, and brushing daily at the correct time. Dental visits were assessed by the question "In the past year, how often did you visit a dental professional?" The response options were dichotomized into <1 time and ≥1 time.

Information about index access to each type of healthcare facility (hospital, community health centre, private practice) was collected in the survey. Access to healthcare facilities was then classified into easy (if the index access to either hospital, community health centre, or private practice was considered easy) and difficult (if none was considered easy to access).

2.4 | Data analysis

Descriptive analysis was employed to summarize the characteristics of the samples. As all of the outcome variables were count data with skewed distributions, Poisson regression or negative binomial regression could be used to evaluate the association of MetS with the number of teeth with BOP, the number of teeth with PD, and the number of sextants with CAL. Because of the over-dispersion of the data, negative binomial models were preferred to Poisson models. Furthermore, to account for the differing number of teeth and sextants measured between individuals, which could have affected the potential numbers of teeth with BOP or PD, or the number of sextants with CAL, the negative binomial models were estimated using an offset variable for the number of examined teeth (for BOP and PD) and the number of examined sextants (for CAL). This enabled a "fair comparison" of the number of possible adverse outcomes across individuals. The offset variable was computed in its log form. We present three models: unadjusted, adjusted for socio-demographic variables, and adjusted for socio-demographic, lifestyle, oral health behaviours, and access to healthcare variables. Rate ratios (RRs) and their 95% confidence intervals (CIs) were reported. Weighting was applied to make the results representative of the target population.

TABLE 1 Characteristics of the study participants

	Unweighted N (weighted %)	Mean (95% CI) percentage of teeth with BOP	Mean (95% CI) percentage of teeth with PD ≥4 mm	Mean (95% CI) percentage of sextants with CAL ≥4 mm
Total subjects	13,359 (100)	30.3 (29.2–31.5)	11.1 (10.3–11.9)	20.3 (19.4–21.2)
Age				
35–64 years	11,963 (89.8)	29.8 (28.6–30.9)	10.7 (9.9–11.5)	18.7 (17.8–19.6)
65+ years	1396 (10.2)	35.4 (33.0–37.8)	15.0 (13.3–16.8)	35.3 (32.7–37.9)
Gender				
Male	5137 (37.9)	31.0 (29.6–32.4)	12.8 (11.7–13.8)	23.8 (22.6–25.0)
Female	8222 (62.1)	29.9 (28.8–31.1)	10.1 (9.4–10.9)	18.1 (17.2–19.1)
Residential location				
Rural	6452 (46.4)	32.7 (31.1–34.3)	11.6 (10.4–12.8)	22.1 (20.7–23.5)
Urban	6907 (53.7)	28.3 (26.8–29.8)	10.7 (9.6–11.8)	18.8 (17.6–19.9)
Educational attainment				
Elementary school or less	7881 (60.3)	32.8 (31.4–34.1)	12.1 (11.2–13.1)	22.7 (21.6–23.8)
Junior and senior high school	4602 (33.7)	27.3 (25.9–28.7)	9.9 (8.9–10.9)	16.9 (15.8–18.1)
Higher education	876 (6.1)	22.9 (20.5–25.2)	7.8 (6.4–9.2)	15.4 (13.4–17.4)
Occupation				
Non-manual workers	3377 (24.7)	26.6 (25.1–28.1)	9.7 (8.6–10.7)	17.0 (15.8–18.2)
Manual workers	4716 (34.4)	34.0 (32.3–35.6)	12.9 (11.7–14.0)	23.7 (22.3–25.1)
Others	5266 (40.9)	29.5 (28.2–30.8)	10.5 (9.7–11.4)	19.5 (18.4–20.6)
Smoking				
Never	9127 (68.2)	30.3 (29.2–31.5)	10.3 (9.6–11.1)	18.6 (17.7–19.5)
Past	940 (7.0)	27.8 (25.4–30.2)	10.6 (9.0–12.2)	19.7 (17.5–22.0)
Current	3292 (24.8)	31.0 (29.4–32.7)	13.4 (12.1–14.6)	25.2 (23.8–26.7)
Chewing tobacco				
Never	12,902 (96.9)	30.3 (29.2–31.5)	11.1 (10.3–11.9)	20.1 (19.2–21.0)
Past	170 (1.2)	25.3 (20.7–30.0)	9.5 (6.2–12.7)	24.5 (18.5–30.5)
Current	287 (2.0)	33.8 (28.8–38.8)	12.4 (9.3–15.4)	27.5 (22.8–32.2)
Tooth-brushing behaviour				
Not daily	375 (2.6)	40.6 (35.9–45.4)	14.6 (11.7–17.5)	33.4 (28.5–38.3)
Daily, incorrect time	12,600 (94.8)	30.1 (29.0–31.3)	11.1 (10.3–11.9)	20.1 (19.2–21.0)
Daily, correct time	384 (2.6)	27.3 (23.7–31.0)	9.2 (6.5–11.9)	14.9 (11.8–18.0)
Dental visit				
<1 time	11,137 (83.4)	30.9 (29.8–32.1)	11.3 (10.4–12.1)	20.6 (19.6–21.5)
≥1 time	2222 (16.7)	27.3 (25.7–29.0)	10.2 (9.2–11.3)	18.9 (17.4–20.4)
Access to healthcare facilities				
Easy	7938 (57.2)	28.8 (27.5–30.1)	10.8 (9.8–11.7)	19.7 (18.7–20.8)
Difficult	5421 (42.9)	32.4 (30.9–34.0)	11.6 (10.6–12.6)	21.0 (19.7–22.3)
Abdominal obesity				
No	7099 (53.0)	31.7 (30.4–33.0)	12.2 (11.2–13.2)	22.4 (21.3–23.5)
Yes	6260 (47.0)	28.8 (27.6–30.1)	9.9 (9.1–10.8)	18.0 (17.0–19.0)

(Continues)

TABLE 1 (Continued)

	Unweighted N (weighted %)	Mean (95% CI) percentage of teeth with BOP	Mean (95% CI) percentage of teeth with PD ≥4 mm	Mean (95% CI) percentage of sextants with CAL ≥4 mm
TG				
Normal	9692 (72.7)	30.2 (29.0–31.4)	10.8 (10.0–11.6)	19.8 (18.9–20.8)
Elevated	3667 (27.3)	30.7 (29.2–32.2)	11.9 (10.8–13.0)	21.5 (20.2–22.8)
HDL-C				
Normal	8065 (60.2)	30.4 (29.2–31.6)	11.2 (10.3–12.1)	21.1 (20.0–22.1)
Reduced	5294 (39.9)	30.2 (28.8–31.6)	11.0 (10.1–12.0)	19.2 (18.1–20.3)
Hypertension				
No	4625 (33.7)	30.0 (28.6–31.4)	10.5 (9.6–11.4)	18.5 (17.3–19.6)
Yes	8734 (66.3)	30.5 (29.3–31.7)	11.4 (10.5–12.3)	21.2 (20.2–22.2)
Hyperglycaemia				
No	7376 (55.8)	29.2 (28.0–30.4)	10.2 (9.3–11.1)	18.3 (17.2–19.3)
Yes	5983 (44.2)	31.8 (30.4–33.1)	12.3 (11.3–13.3)	22.9 (21.8–24.0)
MetS				
No	7879 (59.0)	30.4 (29.2–31.6)	11.1 (10.2–12.0)	20.3 (19.2–21.4)
Yes	5480 (41.0)	30.2 (28.9–31.6)	11.1 (10.2–12.1)	20.3 (19.2–21.4)

Abbreviations: BOP, bleeding on probing; CAL, clinical attachment loss; CI, confidence interval; HDL-C, high-density lipoprotein cholesterol; MetS, metabolic syndrome; PD, pocket depth; TG, triglycerides.

We conducted sensitivity analyses using the E-value methodology to test the robustness of the results to potential unmeasured confounders. E-values indicate the minimum risk ratio magnitude of the association that an unmeasured confounder would need to have with both the exposure and the outcome to explain away the observed effect, conditional on the measured covariates. E-values for both the association estimate and the limit of the confidence interval closest to the null were calculated (Van Der Weele & Ding, 2017).

Data analyses were conducted using the "svyset" command in STATA (version 13.0, Stata Corp, College Station, TX). The significance level was set at a p-value <.05.

3 | RESULTS

Table 1 shows the characteristics of the study participants. The mean (±SD) age of the samples was 50.3 (±10.4) years. The majority were female, lived in urban areas, had received an elementary school education or less, had an occupation listed as "others", had never smoked or chewed tobacco, brushed their teeth daily but at the incorrect time, had not visited a dental clinic in the previous 12 months, had easy access to healthcare facilities, were not abdominally obese, had normal TG and HDL-C, and had hypertension but not hyperglycaemia or MetS. The prevalence of individuals having at least one tooth with BOP, one tooth with PD ≥4 mm, or one sextant with CAL ≥4 mm was 74.9%, 40.7%, and 40.6%, respectively.

Table 2 presents the associations of MetS and its components with the number of teeth with BOP, the number of teeth with PD, and the number of sextants with CAL. MetS was not associated with BOP, PD, and CAL. In the crude models, hyperglycaemia was

associated with a larger number of teeth with BOP, a larger number of teeth with PD ≥4 mm, and a larger number of sextants with CAL ≥4 mm. These associations remained after adjustment for other confounders in models 1–3. However, associations of other MetS components (abdominal obesity, elevated TG, reduced HDL-C, and hypertension) with BOP, PD, and CAL, which were found in the crude model or model 1, no longer existed after the inclusion of all variables in model 3. Table A1 provides details of the full regression results.

The respective E-values of the associations of hyperglycaemia with BOP, PD, and CAL were 1.31, 1.51, and 1.57 for the point estimates and 1.11, 1.21, and 1.37 for the lower confidence limits. These results could be interpreted as unmeasured confounders could negate the observed effects only if they had an RR association with both exposure and outcome of at least 1.31 each for BOP, 1.51 each for PD, and 1.57 each for CAL, above and beyond the measured confounders in our study. Similarly, the RR for an unmeasured confounder that would move the lower confidence limit to 1 would need to be 1.11 for BOP, 1.21 for PD, and 1.37 for CAL, above and beyond the measured confounders. Table A2 provides details of the E-value results.

4 | DISCUSSION

This study examined the relationship between MetS, its components, and periodontitis among Indonesian adults. MetS was not associated with an increased risk of BOP, PD, or CAL. However, hyperglycaemia was the component of MetS consistently shown to be associated with a higher risk of BOP, PD, and CAL.

Our study has some limitations, arising from the study design and the protocol for recording the periodontal data. First, the cross-

TABLE 2 Associations of metabolic syndrome (MetS) and its components with number of teeth with bleeding on probing (BOP), number of teeth with pocket depth (PD), and number of sextants with clinical attachment loss (CAL)

	Number of teeth with BOP RR (95% CI) N = 13,356	Number of teeth with PD ≥4 mm RR (95% CI) N = 13,273	Number of sextants with CAL ≥4 mm RR (95% CI) N = 13,000
MetS (ref: no MetS)			
Crude model	0.99 (0.95–1.04)	1.01 (0.92–1.10)	1.01 (0.95–1.08)
Model 1[a]	1.02 (0.98–1.07)	1.08 (0.99–1.18)	1.05 (0.99–1.13)
Model 2[b]	1.02 (0.98–1.07)	1.08 (0.99–1.18)	1.05 (0.99–1.13)
Hyperglycaemia (ref: not hyperglycaemia)			
Crude model	1.08 (1.04–1.13)**	1.20 (1.10–1.31)**	1.27 (1.20–1.35)**
Model 1[a]	1.06 (1.01–1.11)*	1.15 (1.05–1.25)*	1.16 (1.09–1.23)**
Model 2[b]	1.06 (1.01–1.11)*	1.14 (1.05–1.25)*	1.15 (1.08–1.23)**
Model 3[c]	1.06 (1.01–1.11)*	1.13 (1.03–1.23)*	1.15 (1.08–1.23)**
Abdominal obesity (ref: not obese)			
Crude model	0.91 (0.87–0.95)**	0.82 (0.75–0.89)**	0.82 (0.77–0.87)**
Model 1[a]	0.96 (0.92–1.01)	0.94 (0.86–1.03)	0.96 (0.90–1.03)
Model 2[b]	0.97 (0.93–1.02)	0.95 (0.87–1.04)	0.97 (0.91–1.04)
Model 3[c]	0.96 (0.91–1.00)	0.91 (0.83–1.00)	0.94 (0.88–1.01)
Elevated TG (ref: normal TG)			
Crude model	1.01 (0.97–1.06)	1.11 (1.02–1.21)*	1.10 (1.03–1.17)*
Model 1[a]	1.03 (0.98–1.07)	1.10 (1.01–1.19)*	1.06 (0.99–1.13)
Model 2[b]	1.03 (0.98–1.08)	1.10 (1.01–1.19)*	1.05 (0.99–1.13)
Model 3[c]	1.02 (0.98–1.07)	1.07 (0.98–1.16)	1.04 (0.97–1.11)
Reduced HDL-C (ref: normal HDL-C)			
Crude model	0.99 (0.95–1.04)	0.98 (0.91–1.07)	0.90 (0.85–0.96)*
Model 1[a]	1.02 (0.98–1.07)	1.08 (0.99–1.17)	1.02 (0.96–1.09)
Model 2[b]	1.03 (0.98–1.07)	1.08 (0.99–1.17)	1.01 (0.95–1.08)
Model 3[c]	1.02 (0.98–1.07)	1.05 (0.97–1.14)	0.99 (0.93–1.06)
Hypertension (ref: not hypertension)			
Crude model	1.01 (0.97–1.06)	1.09 (1.00–1.18)*	1.15 (1.07–1.22)**
Model 1[a]	0.99 (0.95–1.04)	1.04 (0.96–1.14)	1.04 (0.97–1.11)
Model 2[b]	0.99 (0.95–1.04)	1.05 (0.96–1.14)	1.05 (0.98–1.12)
Model 3[c]	0.99 (0.95–1.04)	1.05 (0.96–1.14)	1.04 (0.97–1.11)

Note: The outcomes were the number of teeth with BOP, the number of teeth with PD, and the number of sextants with CAL. The exposures were MetS or its components. RRs and 95% CI were derived from negative binomial regression analyses. The log form of the number of examined teeth for BOP and PD was used as an offset variable for the analyses of BOP and PD outcomes, respectively, while the log form of the number of examined sextants was used as an offset variable for the analysis of CAL outcome.

Abbreviations: CI, confidence interval; HDL-C, high-density lipoprotein cholesterol; RR, rate ratio; TG, triglycerides.

[a]Model 1 was adjusted for age, gender, residential location, education, and occupation.
[b]Model 2 was model 1 additionally adjusted for smoking status, chewing tobacco status, tooth-brushing behaviour, dental visit, and access to healthcare facilities.
[c]Model 3 was model 2 additionally adjusted for other MetS components.
*p-Value < .05; **p-Value < .001.

sectional design of this study limited our ability to establish causality. Second, the analyses in our study were limited to the available data, and thus there might have been effects from residual unobserved confounders, such as income or wealth, alcohol use, dietary intake, and physical activity. It has also been suggested that various dimensions of tobacco use be measured (e.g., type, dose, duration, time

since quitting) (Sun et al., 2012; Banyai et al., 2021; Leite & Nascimento, 2021). For example, longer dip duration and cumulative exposure to smokeless tobacco products in South Asia (e.g., Naswar) were associated with an increased risk of developing oral cancer (Khan et al., 2017), which is an important aspect of the periodontal examination. Nevertheless, the E-values for the association of

hyperglycaemia with CAL in our study were larger than other known confounders of periodontitis, such as age or smoking (Table A1), which might suggest that bias arising from unmeasured confounders in this study would not be large.

Further limitations also arose from the survey protocol for recording the periodontal data. First, both PD and CAL were recorded in the form of scores (ranges), and thus it was not possible to determine the severity of periodontitis (the mean of PD and CAL) in individuals. The full extent of CAL in an individual could not be demonstrated, as the assessments were limited to sextants, primarily relying on the use of index teeth. However, partial recording of CAL was still considered a feasible way to capture the past periodontitis experience of the population. Second, we were not able to develop a case definition for periodontitis by combining information about CAL and PD or CAL and BOP on the index teeth. According to the protocol, in the absence of the index tooth of the sextant, all of the present teeth in that sextant were examined, and the highest score was recorded as the score for the sextant. The tooth that was finally used to measure CAL of the sextant was not identified (World Health Organisation, 2013). Future studies should consider having a recording protocol that could facilitate a case definition for periodontitis be developed. Nevertheless, although we cannot provide a case definition for periodontitis, the three parameters of periodontal diseases that we assessed complemented one another and, taken together, provided useful information on the population's periodontal condition. BOP and PD are indicators of periodontal inflammation, and CAL reflects accumulated periodontal damage (Lai et al., 2007; Kongstad et al., 2009; Zimmermann et al., 2015).

Notwithstanding these limitations, this study is among the few to report the periodontal condition of a sample of Indonesian adults and the first to investigate the association between MetS and periodontal diseases in this population. Moreover, only a few studies have examined this association in Southeast Asian populations. The survey itself was the first national health survey in Indonesia that included the clinical assessment of oral health following the WHO guideline (World Health Organisation, 2013), which could facilitate international comparisons.

Our study did not demonstrate the associations of MetS with BOP, PD, and CAL reported in other studies (Shimazaki et al., 2007; Alhabashneh et al., 2015; Iwasaki et al., 2015). Instead, our findings were in line with those of studies showing a null association between MetS and periodontitis (LaMonte et al., 2014; Zuk et al., 2017). The inconsistent findings might be due to differences in confounding factors, study populations (variations in genetic background, age, and sex), and the diagnostic and clinical criteria used to define MetS and periodontitis (Shimazaki et al., 2007; Timonen et al., 2010). Furthermore, a recent study demonstrated that the association between MetS and periodontitis was sensitive to the analytical method employed. No association was observed when MetS and periodontitis were treated as observed categorical variables, but a positive association was demonstrated when multiple dimensions of both diseases were accounted for by latent or construct variables using structural equation modelling (Nascimento et al., 2019).

Similarly, our study did not find associations between abdominal obesity, dyslipidaemia, or hypertension and BOP, PD, or CAL. These findings were similar to those of previous studies (Benguigui et al., 2010; Iwasaki et al., 2015; Alhabashneh et al., 2015; Zuk et al., 2017). It has been suggested that dyslipidaemia and hypertension might have an additive effect on periodontal diseases risk, but only if they are complemented by hyperglycaemia and/or obesity (Lamster & Pagan, 2017). Another study argued that it is the insulin resistance, which increases with obesity, that plays a predominant role, as it could mediate the relationship between obesity and periodontitis (Benguigui et al., 2010).

Turning to hyperglycaemia, our study showed that it was the component of MetS consistently associated with BOP, PD, and CAL. Our findings that hyperglycaemia was associated with periodontitis were in line with those of previous studies (Shimazaki et al., 2007; Benguigui et al., 2010), including a joint consensus statement by the European Federation of Periodontology (EFP) and the International Diabetes Federation (IDF) (Sanz et al., 2018). Hyperglycaemia affects periodontitis through a network of mechanisms. First, it stimulates the formation of advanced glycation end-products (AGEs) and the interaction of AGEs with their receptors (RAGEs), leading to immune cell dysfunction, alterations in the phenotypes and functions of certain cells, and cytokine imbalances (elevated TNF-α, IL-1β, and IL-6) (Taylor et al., 2013; Sanz et al., 2018). Diabetic individuals with periodontitis have polymorphonuclear leukocytes with decreased chemotaxis and phagocytosis and altered superoxide production; these characteristics cause them to accumulate in the periodontium and form abscess-like structures (Shetty et al., 2008; Lamster & Pagan, 2017). Second, hyperglycaemia increases the level of reactive oxygen species (ROS) and oxidative stress, both directly and indirectly via the AGE–RAGE axis, inducing alterations in cytokine profiles. Third, it increases the RANKL/OPG ratios, both directly and indirectly via the AGE–RAGE axis, promoting inflammation and destruction. Moreover, most of the elements in these mechanisms have a bidirectional association, whereby the pro-inflammatory state generates the formation of AGEs, ROS, and adipokines, increases the RANKL/OPG ratio, and promotes the growth of pathogenic subgingival bacteria (Taylor et al., 2013).

Considering the extensive evidence linking diabetes and periodontitis, the EFP and the IDF create consensus guidelines for physicians, dental professionals, and patients to enhance the prevention, early diagnosis, and co-management of diabetes and periodontitis. Periodontal therapy in diabetic patients is recommended as safe and effective and is associated with short-term HbA1C reduction (Sanz et al., 2018). Indonesia might benefit from adopting the guidelines into their healthcare context, incorporating oral health into routine diabetes care.

5 | CONCLUSION

The prevalence of periodontal diseases in Indonesia is high. MetS was not associated with BOP, PD, or CAL in our study. Hyperglycaemia was the component of MetS most consistently shown to be positively associated with BOP, PD, and CAL. Incorporating oral disease prevention strategies into the management of systemic diseases could

reduce the burden of these diseases. Individuals with hyperglycaemia should be checked for periodontal diseases. Future longitudinal studies are warranted to explore the temporal association of MetS and its components with periodontal diseases.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Cornelia Melinda Adi Santoso: Conceptualization; data curation; methodology; formal analysis; interpretation of data; writing—original draft preparation; writing—review and editing. **Taufan Bramantoro**: Interpretation of data; writing—review and editing. **László Kardos**: Methodology; interpretation of data; writing—review and editing. **Dóra Fanni Szakács**: Writing—review and editing. **Attila Nagy**: Data curation; methodology; formal analysis; interpretation of data; writing—review and editing; supervision.

ETHICS STATEMENT

Since this study was a secondary analysis, new ethical clearance was not required.

DATA AVAILABILITY STATEMENT

The data analysed in this study are not publicly available due to the restricted policy of the National Institute of Health Research and Development (NIHRD), Ministry of Health, Indonesia. Data can be requested from the Data Management Laboratory of NIHRD through an official written permission.

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APPENDIX

TABLE A1 Full regression results

Variables	Number of teeth with BOP (N = 13,356)		Number of teeth with PD (N = 13,273)		Number of sextants with CAL (N = 13,000)	
	Adjusted RR (95% CI)[a]	Adjusted RR (95% CI)[b]	Adjusted RR (95% CI)[a]	Adjusted RR (95% CI)[b]	Adjusted RR (95% CI)[a]	Adjusted RR (95% CI)[b]
Age	1.01 (1.00–1.01)**	1.00 (1.00–1.01)**	1.02 (1.01–1.02)**	1.02 (1.01–1.02)**	1.03 (1.03–1.03)**	1.03 (1.03–1.03)**
Gender (ref: female)						
Male	1.08 (1.01–1.15)*	1.06 (0.99–1.14)	1.19 (1.07–1.32)*	1.14 (1.03–1.28)*	1.19 (1.09–1.30)**	1.16 (1.06–1.26)*
Residential location (ref: rural)						
Urban	0.95 (0.88–1.03)	0.96 (0.88–1.03)	1.02 (0.88–1.19)	1.03 (0.88–1.20)	0.93 (0.84–1.03)	0.93 (0.85–1.03)
Education (ref: elementary school or less)						
High school	0.92 (0.87–0.97)*	0.93 (0.88–0.98)*	0.94 (0.84–1.04)	0.94 (0.85–1.05)	0.94 (0.87–1.02)	0.95 (0.88–1.03)
Higher education	0.79 (0.71–0.88)**	0.79 (0.71–0.89)**	0.74 (0.61–0.91)*	0.75 (0.62–0.92)*	0.82 (0.71–0.95)*	0.83 (0.72–0.95)*
Occupation (ref: others)						
Manual workers	1.08 (1.02–1.15)*	1.08 (1.02–1.15)*	1.09 (0.98–1.22)	1.09 (0.97–1.21)	1.04 (0.96–1.13)	1.04 (0.96–1.12)
Non-manual workers	0.95 (0.89–1.00)	0.95 (0.89–1.01)	0.92 (0.82–1.03)	0.92 (0.82–1.03)	0.89 (0.82–0.97)*	0.89 (0.82–0.97)*
Smoking (ref: never)						
Former	0.88 (0.80–0.97)*	0.89 (0.80–0.98)*	0.89 (0.75–1.06)	0.90 (0.76–1.07)	0.89 (0.78–1.01)	0.90 (0.79–1.02)
Current	0.93 (0.86–1.00)	0.93 (0.86–1.00)*	1.10 (0.97–1.25)	1.10 (0.97–1.24)	1.14 (1.04–1.25)*	1.14 (1.04–1.25)*
Chewing tobacco (ref: never)						
Former	0.85 (0.70–1.03)	0.85 (0.71–1.03)	0.81 (0.55–1.18)	0.82 (0.56–1.22)	0.98 (0.76–1.26)	0.98 (0.76–1.27)
Current	1.05 (0.90–1.22)	1.05 (0.90–1.22)	0.99 (0.78–1.24)	0.99 (0.79–1.25)	1.09 (0.91–1.30)	1.10 (0.92–1.31)
Toothbrushing (ref: not daily)						
Daily, incorrect	0.86 (0.76–0.97)*	0.86 (0.77–0.97)*	1.04 (0.84–1.28)	1.04 (0.84–1.28)	0.91 (0.78–1.07)	0.91 (0.78–1.07)
Daily, correct	0.82 (0.69–0.97)*	0.83 (0.70–0.98)*	0.93 (0.66–1.30)	0.93 (0.66–1.31)	0.74 (0.57–0.96)*	0.75 (0.58–0.97)*
Dental visit (ref: no)						
Yes	0.92 (0.87–0.98)*	0.92 (0.87–0.98)*	0.95 (0.86–1.06)	0.96 (0.86–1.07)	1.00 (0.92–1.09)	1.01 (0.93–1.09)
Access to healthcare (ref: difficult)						
Easy	0.93 (0.87–0.98)*	0.93 (0.88–0.98)*	0.99 (0.88–1.10)	0.99 (0.89–1.10)	1.03 (0.95–1.11)	1.02 (0.95–1.11)
Metabolic syndrome (ref: no)						
Yes	1.02 (0.98–1.07)	N/A	1.08 (0.99–1.18)	N/A	1.05 (0.99–1.13)	N/A
Hyperglycaemia (ref: no)						
Yes	N/A	1.06 (1.01–1.11)*	N/A	1.13 (1.03–1.23)*	N/A	1.15 (1.08–1.23)**
Abdominal obesity (ref: no)						
Yes	N/A	0.96 (0.91–1.00)	N/A	0.91 (0.83–1.00)	N/A	0.94 (0.88–1.01)
Elevated TG (ref: no)						
Yes	N/A	1.02 (0.98–1.07)	N/A	1.07 (0.98–1.16)	N/A	1.04 (0.97–1.11)
Reduced HDL-C (ref: no)						
Yes	N/A	1.02 (0.98–1.07)	N/A	1.05 (0.97–1.14)	N/A	0.99 (0.93–1.06)
Hypertension (ref: no)						
Yes	N/A	0.99 (0.95–1.04)	N/A	1.05 (0.96–1.14)	N/A	1.04 (0.97–1.11)

Note: The outcomes were the number of teeth with BOP, the number of teeth with PD, and the number of sextants with CAL. RRs and 95% CIs were derived from negative binomial regression analyses. The log form of the number of examined teeth for BOP and PD was used as an offset variable for the analyses of BOP and PD outcomes, respectively, while the log form of the number of examined sextants was used as an offset variable for the analysis of CAL outcome.

Abbreviations: BOP, bleeding on probing; CAL, clinical attachment loss; CI, confidence interval; HDL-C, high density lipoprotein cholesterol; MetS, metabolic syndrome; N/A, not applicable; PD, pocket depth; RR, rate ratio; TG, triglycerides.

[a]Model was simultaneously adjusted for age, gender, residential location, education, occupation, smoking status, chewing tobacco status, tooth-brushing behaviour, dental visit, access to healthcare facilities, and MetS.

[b]Model was simultaneously adjusted for age, gender, residential location, education, occupation, smoking status, chewing tobacco status, tooth-brushing behaviour, dental visit, access to healthcare facilities, hyperglycaemia, abdominal obesity, elevated TG, reduced HDL-C, and hypertension.

*p-Value < .05; **p-Value < .001.

TABLE A2 *E*-values for observed associations of metabolic syndrome (MetS) and its components with the number of teeth with bleeding on probing (BOP), the number of teeth with pocket depth (PD), and the number of sextants with clinical attachment loss (CAL)

	Number of teeth with BOP	Number of teeth with PD ≥4 mm	Number of sextants with CAL ≥4 mm
	RR (95% CI)	RR (95% CI)	RR (95% CI)
	N = 13,356	*N* = 13,273	*N* = 13,000
MetS			
Observed association	1.02 (0.98–1.07)	1.08 (0.99–1.18)	1.05 (0.99–1.13)
E-value for point estimate	1.16	1.37	1.28
E-value for confidence interval	1.00	1.00	1.00
Hyperglycaemia			
Observed association	1.06 (1.01–1.11)	1.13 (1.03–1.23)	1.15 (1.08–1.23)
E-value for point estimate	1.31	1.51	1.57
E-value for confidence interval	1.11	1.21	1.37
Abdominal obesity			
Observed association	0.96 (0.91–1.00)	0.91 (0.83–1.00)	0.94 (0.88–1.01)
E-value for point estimate	1.25	1.43	1.32
E-value for confidence interval	1.00	1.00	1.00
Elevated TG			
Observed association	1.02 (0.98–1.07)	1.07 (0.98–1.16)	1.04 (0.97–1.11)
E-value for point estimate	1.16	1.34	1.24
E-value for confidence interval	1.00	1.00	1.00
Reduced HDL-C			
Observed association	1.02 (0.98–1.07)	1.05 (0.97–1.14)	0.99 (0.93–1.06)
E-value for point estimate	1.16	1.28	1.11
E-value for confidence interval	1.00	1.00	1.00
Hypertension			
Observed association	0.99 (0.95–1.04)	1.05 (0.96–1.14)	1.04 (0.97–1.11)
E-value for point estimate	1.11	1.28	1.24
E-value for confidence interval	1.00	1.00	1.00

Abbreviations: CI, confidence interval; HDL-C, high-density lipoprotein cholesterol; RR, rate ratio; TG, triglycerides.