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Research paper

Association between periodontal disease and pericardial adipose tissue in patients with cardiovascular disease

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ABSTRACT

Background: Periodontal disease (PD) is associated with an increased risk of cardiovascular disease (CVD). Pericardial adipose tissue (PAT) is known as a marker of progressive CVD. This study sought to assess the association between PD and PAT in patients with CVD.

Methods: We retrospectively investigated 135 patients admitted for CVD who underwent computed tomography coronary angiography (CTCA) and periodontal examinations. Periodontal assessment using the community periodontal index (CPI) was based on the probing pocket depth around teeth. Patients with CPI $\geq$3 were categorized as having PD. PAT volume was measured with a quantitative semi-automated procedure using CTCA images. Patients were divided into tertiles according to PAT volume. Baseline characteristics and PD findings were compared among the tertiles.

Results: Eighty-six patients were diagnosed with PD (63.7 %). Mean PAT volume was 181.4 ml, and patients were categorized as small-PAT (PAT <148.9 ml), intermediate-PAT (148.9 ml $\leq$ PAT $\leq$204.6 ml), and large-PAT (PAT >204.6 ml). The prevalence of PD was significantly higher in large-PAT (38/46, 82.6 %) than in small-PAT (18/45, 40.0 %) and intermediate-PAT (30/44, 68.2 %) patients. Multivariate logistic regression analysis showed that body weight, history of hypertension, and the presence of PD were independent predictors for large-PAT (odds ratio [OR]: 1.12, $P < 0.001$, OR: 3.97, $P = 0.017$, and OR: 4.18, $P = 0.0078$, respectively).

Conclusion: The presence and severity of PD were significantly correlated with PAT volume, which has been associated with progressive CVD. Further prospective studies are warranted to assess the impact of PD on the onset and outcomes of CVD.

1. Introduction

Pericardial adipose tissue (PAT), a type of visceral fat tissue, is known to be a marker of the progression of cardiovascular disease (CVD) [1–4]. Pericardial fat, which surrounds the heart, includes epicardial (enclosed between the myocardium and visceral pericardium) and paracardial (surrounded the pericardium) fat [4–6]. Some studies have shown that visceral and hepatic fat might promote CVD risk and myocardial remodeling [7]; similarly, several investigators reported that pericardial fat, which is considered to be a visceral-like fat deposit, increases the frequency of atrial fibrillation, coronary artery disease, and atherosclerotic vascular disease [8–10]. Multi-detector computed tomography (MDCT) is a non-invasive imaging modality that provides high resolutional, three-dimensional reconstructed images of the heart. Previous studies have shown that cardiac CT enabled volumetric quantification of PAT, and an increased volume of pericardial fat was

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associated with susceptibility to adverse cardiac events [4,7,11].

Periodontal disease (PD) is a chronic infectious disease characterized by inflammatory changes in periodontal tissue [12,13]. Periodontal inflammation initiates local vascular inflammation, which induces the proliferation of inflammatory cells and cytokine release in the periodontium, and further leads to systemic inflammation [14,15]. Several studies have shown an association between PD and the development of CVD or risk factors [13,16].

Considering that both PD and PAT have been associated with the development or progression of cardiovascular diseases, there might exist a common pathophysiological substrate such as systemic inflammation that connects PD and PAT. Nevertheless, no studies have provided a direct comparison between PAT and the presence of PD. Therefore, the present study sought to assess the association between the presence of PD and PAT volume.

2. Methods

2.1. Study population

This was a post-hoc analysis of a prospective observational registry for the assessment of the association between cardiovascular disease and periodontal disease that was conducted between May 2012 and August 2015 at Tokyo Medical and Dental University Hospital, Tokyo, Japan. The registry enrolled 1000 consecutive patients with written informed consent who were admitted to the Department of Cardiovascular Medicine as described elsewhere [17,18]. The reasons for admission of the participants are summarized in Table 1. All patients underwent a periodontal examination by an experienced periodontist (N.A.) during hospitalization. The study protocol was approved by the institutional review board (IRB) of the Tokyo Medical and Dental University (MD2000–1165). An ancillary study, which was additionally approved by the IRB in 2020 (M2020–020), was performed to collect additional clinical information and long-term outcomes by reviewing medical records. Out of a total of 1000 patients enrolled in the registry, we identified 144 patients who underwent computed tomography coronary angiography (CTCA) within a year before the periodontal examination, and these patients were investigated in the present study. Patients with a history of coronary artery bypass surgery and thoracotomy were excluded. Due to the significant impact of smoking on periodontal status, current smokers were excluded. We defined Prior smoker as someone who has smoked >100 cigarettes in their own life and has not smoked in the last 1 month ago. Patients with suboptimal CTCA imaging quality were also excluded. In total, 135 patients who underwent a periodontal examination and CTCA imaging were included in the analysis (Fig. 1). The patients were divided into three groups stratified by PAT volume. Baseline characteristics, angiographic findings, periodontal assessment, and CTCA findings of the small-PAT and intermediate-PAT groups were compared with those of the large-PAT group. This study was performed in compliance with the Declaration of Helsinki for investigation in humans.

2.2. Computed tomography analysis

CTCA was performed using a 64-slice CT scanner (Aquilion 64. Toshiba, Tokyo, Japan). Oral beta-blockers (metoprolol) or intravenous injection of landiolol hydrochloride were administered to the patients to achieve a target heart rate ≤ 65 bpm. Immediately before scanning, 0.3 or 0.6 mg of sublingual nitroglycerine was also administered. A non-contrast-enhanced CT was acquired to assess coronary artery calcification with prospective triggering at 75 % of the RR interval with 3-mm slice thickness. CTCA scans were triggered using an automatic bolus-tracking technique with a region of interest placed in the ascending aorta. Images were acquired after a bolus injection of 40–60 ml contrast (iopamidol, Bayer Yakuhin Ltd., Japan) at a rate of 3–6 ml/s, using prospective ECG-triggering or retrospective ECG gating with tube current modulation. Acquisition and reconstruction parameters for the patients in our study were 120 kVp, tube current of 50 to 750 mA, gantry rotation speed of 500 ms per rotation, helical pitch of 8–18, field matrix of 512 × 512, and scan thickness of 0.5 mm. All scans were performed during a single breath-hold. Images were reconstructed at a window centered at 75 % of the RR interval to coincide with left ventricular diastasis.

Table 1
Baseline patient characteristics.

	Total	PD group	Non-PD group	p
N	135	86	49	
Patient characteristics				
Age, y	70 (64–75)	70 (65–75)	69 (62–75)	0.83
Female sex	30 (22.2)	16 (18.6)	14 (28.6)	0.20
Body weight, kg	64.1 (58.4–71.8)	65.1 (59.9–72.4)	62.8 (57.3–70.5)	0.29
BMI, kg/m^2	24.2 (22.5–26.6)	24.5 (22.3–26.7)	23.8 (22.5–26.1)	0.42
Diabetes mellitus	47 (34.8)	32 (37.2)	15 (30.6)	0.46
Hypertension	89 (65.9)	62 (72.1)	27 (55.1)	0.059
Dyslipidemia	72 (53.3)	47 (54.7)	25 (51.0)	0.72
Past Smoker	92 (68.1)	61 (70.9)	31 (63.3)	0.44
Creatinine, mg/dl	0.87 (0.75–1.01)	0.87 (0.75–1.02)	0.87 (0.73–1.00)	0.45
eGFR, ml/min./1.73m^2	63.1 ± 17.7	62.4 ± 17.9	64.3 ± 17.4	0.58
HbA1c (%)	6.0 (5.6–6.4)	6.0 (5.6–6.4)	6.0 (5.5–6.6)	0.74
C- reactive protein, mg/dl	0.09 (0.05–0.21)	0.11 (0.07–0.22)	0.06 (0.03–0.14)	<0.001
Total cholesterol, mg/dl	177 ± 38	176.5 ± 37.2	178.5 ± 38.9	0.77
LDL cholesterol, mg/dl	102 ± 31	100.4 ± 31.2	104.4 ± 30.9	0.48
Triglyceride, mg/dl	53 (46–64)	125 (101–181)	110 (80–149)	0.031
BNP, pg/ml	121 (92–172)	46.1 (19.9–105.7)	45.7 (29.7–73.6)	0.82
Medication, n (%)				
ACE-I or ARB	95 (70.4)	57 (66.3)	29 (59.2)	0.46
β -Blocker	74 (54.8)	48 (55.8)	26 (53.1)	0.86
Statin	99 (73.3)	63 (73.3)	36 (73.5)	1.0
Echocardiographic EF, %	66.0 (57.2–71)	65.9 (57.6–71)	66.0 (56.0–71)	0.79
Cardiovascular disease, n				
Ischemic heart disease	95 (70.4)	60 (69.8)	35 (71.4)	0.95
Congestive heart failure	6 (4.4)	4 (4.7)	2 (4.1)	
Arrhythmia disease	28 (20.7)	17 (19.8)	11 (22.4)	
Cardiomyopathy	2 (1.5)	2 (2.3)	0 (0)	
Others	4 (3.0)	3 (3.5)	1 (2.0)	

Variables are expressed as n (%), median (interquartile range), or mean ± standard deviation.
ACE-I indicates angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker; BNP, brain natriuretic peptide; EF, ejection fraction; eGFR, estimated glomerular filtration rate; HbA1c, glycated hemoglobin; and LDL, low-density lipoprotein.

2.3. Quantification of pericardial adipose tissue

Pericardial fat volume was assessed using contrast-enhanced images on reconstructed three-dimensional views as previously published [5,19]. Quantitative measurements of PAT volume were performed using SYNAPSE VINCENT software (Fujifilm Co., Ltd., Tokyo, Japan). Cross-sectional axial images between 15 mm above and 30 mm below the left main coronary artery were selected as the region of interest (ROI) for the analysis, because this area includes the pericardial fat located around the proximal coronary arteries (left main coronary, left

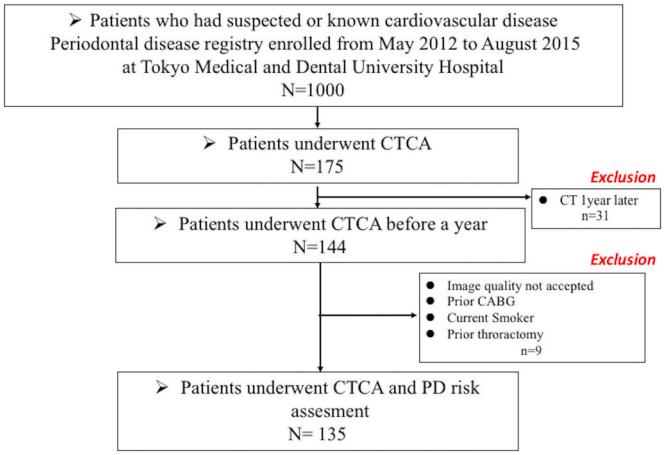

Fig. 1. Study population
Abbreviations: CABG, coronary artery bypass grafting; CT, computed tomography; PD, periodontal disease.

anterior descending, right coronary, and circumflex arteries). The anterior border of the pericardial fat volume was defined by the chest wall and the posterior border was delineated by the chest and the bronchus. Pericardial fat includes both epicardial (located within the pericardium) and paracardial fat (superficial to the pericardium) [4]. Within the ROI, we defined contiguous voxels with the CT attenuation between −190 HU and − 30 HU as adipose tissue, which is automatically identified within the ROI by the software. The software also calculated the voxel volume and mean CT density of the PAT (CT_{PAT}) (Supplemental figure).

2.4. Clinical periodontal assessments

A clinical periodontal assessment was performed by a periodontist certified by the Japanese Society of the Periodontology (N.A). The remaining teeth were counted, and the probing pocket depth (PPD), bleeding on probing (BOP), community periodontal index (CPI), and clinical attachment level (CAL) were recorded at six points (buccal-mesial, mid-buccal, buccal-distal, lingual-mesial, mid-lingual, and lingual-distal) on the right and left upper molar, upper and lower incisor, and right and left lower molar with a manual probe (PCP-UNC 15, Hu-Friedy, Chicago, USA). PPD was defined as the distance from the gingival margin to the bottom of the gingival pocket. BOP was defined as bleeding from the gingiva at the probe tip. CPI is a measure that evaluates three indicators of periodontal condition: gingival bleeding, calculus, and periodontal pockets, using a five-point scale from 0 to 4 codes (code 0, healthy; code 1, bleeding observed, directly or by using a mouth mirror, after probing; code 2, calculus detected during probing; code 3, PPD 4–5 mm, gingival margin within the black band on the probe; and code 4, PPD 6 mm or more, black band on the probe not visible). In the present study, PD was defined as a maximal CPI of ≥3. CAL referred to the distance from the cemento-enamel junction to the bottom of the pocket.

2.5. Statistical analysis

The statistical analysis was performed using SPSS version 23.0 (IBM Corp., Armonk, NY, USA) and R version 4.1.2 for Mac. Categorical data are expressed as absolute frequencies and percentages, and were compared using the χ^2 test or Fisher's exact test, as appropriate. Continuous variables are expressed as mean ± standard deviation for normally distributed variables and as median (25th–75th percentile) for non-normally distributed variables. Analysis was performed with the Mann–Whitney *U* test or Kruskal–Wallis test for variables with a non-normal distribution and with Student's *t*-test or analysis of variance for variables with a normal distribution. Correlations between two parameters were evaluated using linear regression analysis. Univariate and multivariable regression analyses were performed to identify the determinants of large-PAT. The associated variables on patients' clinical characteristics, angiographic findings, hemodynamic variables during catheterization, or thermodilution data in the univariate analysis ($P < 0.10$) were entered into the multivariable model. A *P*-value of <0.05 indicated statistical significance.

3. Results

3.1. Patient characteristics and periodontal examination

Table 1 shows the baseline characteristics of the patients. In the total cohort, the median age was 70 years (64–75 years) and females accounted for 22.2 %. Cardiovascular disease, for which the patients were admitted, consisted of ischemic heart disease (70.4 %), arrhythmia disease (20.7 %), congestive heart failure (4.4 %), non-ischemic cardiomyopathy (1.5 %), and others (3.0 %). Eighty-six patients (63.7 %) were diagnosed with PD, which was defined as having a maximal CPI of ≥3, and were categorized into the PD group. There were no statistically significant differences in age; sex; coronary risk factors such as diabetes mellitus, dyslipidemia, or hypertension; or medication at the time of enrollment between the two groups. In terms of laboratory data, the PD group had significantly higher C-reactive protein and triglyceride levels compared with the non-PD group. Table 2 summarizes the periodontal findings of the patients. BOP was significantly more frequently observed in the PD group than in the non-PD group, whereas no significant differences were observed in the number of residual teeth or dental caries. PPD and PAL were significantly greater in the PD group than in the non-PD group.

3.2. PAT volume and PD

The median PAT volume was 181.4 ml (137.0–228.0), and CT_{PAT} was −81.5 ± 5.2 HU in the total cohort. CT_{PAT} showed an inverse linear correlation with PAT volume (R = -0.63, $P < 0.001$) (Fig. 2). PAT volume was significantly greater in the PD group than in the non-PD group (Table 3). Conversely, CT_{PAT} was significantly lower in the PD group than in the non-PD group (Table 3). Moreover, average PPD and CPI showed significant linear correlations with PAT volume (Fig. 3 A and B). Thereafter, patients were divided by the tertile of the PAT volume into

Table 2
Periodontal assessments.

	Total	PD group	Non-PD group	p
N	135	86	49	
Periodontal disease, n (%)	86 (63.7 %)	86 (100 %)	0 (0 %)	–
CPI 0, n (%)	16 (11.9 %)	–	16 (11.9 %)	–
CPI 1, n (%)	8 (5.9 %)	–	8 (5.9 %)	–
CPI 2, n (%)	25 (18.5 %)	–	25 (18.5 %)	–
CPI 3, n (%)	53 (39.3 %)	53 (39.3 %)	–	–
CPI 4, n (%)	33 (24.4 %)	33 (24.4 %)	–	–
Bleeding on probing (BOP), n (%)	100 (74 %)	79 (91.9)	21 (42.9)	<0.001
Residual teeth	23 (16.5–27)	23 (18–27)	24 (9–28)	0.86
Dental caries, n (%)	60 (44.4 %)	43 (50.0)	17 (34.7)	0.11
Periodontal Probing depth (PPD), mm	2.33 (2.08–2.89)	2.67 (2.33–3.17)	2.06 (1.83–2.14)	<0.001
Clinical Attachment Level (CAL), mm	2.97 (2.32–3.67)	3.24 (2.62–3.89)	2.22 (2.08–3.14)	<0.001

Variables are expressed as n (%), median (interquartile range), or mean ± standard deviation.
CAL indicates clinical attachment level; CPI, community periodontal index; and PPD, periodontal probing depth.

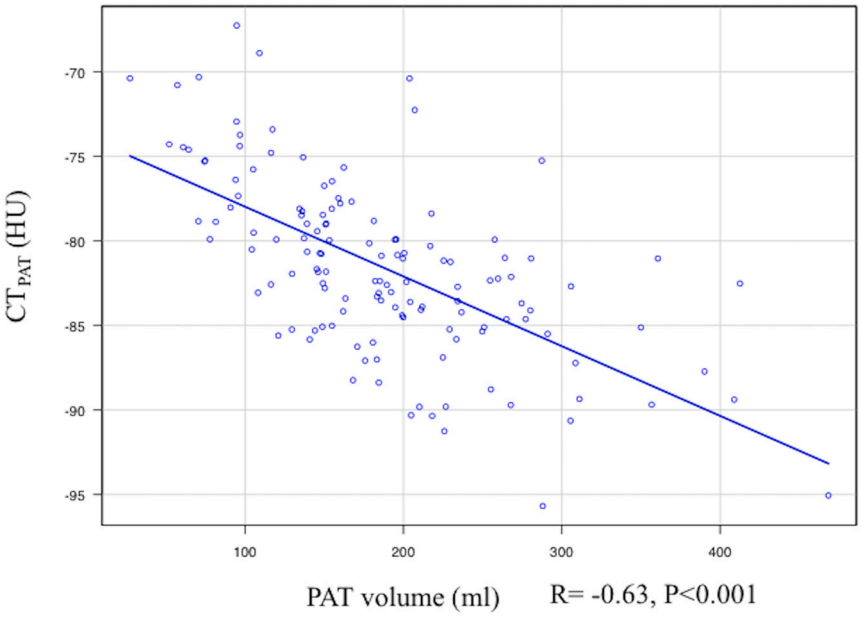

Fig. 2. Linear correlation between pericardial fat volume and mean CT density of pericardial fat
Scatter plot showing linear relationships between the PAT volume and mean CT density of pericardial fat (CT_{PAT}). There is a significant correlation between PAT volume and CT_{PAT}.
Abbreviations: CT, computed tomography; PAT, pericardial adipose tissue.

Table 3
Coronary CT findings.

	Total	PD group	Non-PD group	p
N	135	86	49	
Coronary CT findings				
PAT volume, ml	181.4 (137.0–228.0)	195.9 (151.2–254.2)	144.1 (105.4–175.8)	<0.001
CT_{PAT}, HU	−81.5 ± 5.2	−82.3 ± 5.4	−80.1 ± 4.6	0.019

Variables are expressed as n (%), median (interquartile range), or mean ± standard deviation.
CT indicates computed tomography; HU, Hausfield unit; PAT, pericardial adipose tissue; and CT_{PAT}, mean CT density of pericardial adipose tissue.

three groups: small-PAT (PAT<148.9 ml); intermediate-PAT (148.9 ≤ PAT≤204.6 ml); and large-PAT (PAT>204.6 ml). PD was significantly less frequent in small-PAT (18/45, 40.0 %) than in intermediate-PAT (30/44, 68.2 %) or in large-PAT (38/46, 82.6 %) (Fig. 4).

3.3. Determinants of large-PAT

Univariate and multivariate analyses to predict large-PAT were performed (Table 4). In the univariate analyses, male sex, greater body weight, hypertension, higher triglyceride level, and PD were significantly associated with large-PAT. On multivariate analysis, body weight (odds ratio [OR] 1.12, 95 % confidence interval [CI] 1.06–1.17, $P < 0.001$), hypertension (OR: 3.97, 95%CI 1.29–12.3, $P = 0.017$), and PD (OR 4.18, 95%CI 1.46–12.0, $P = 0.008$) remained independent predictors of large-PAT.

4. Discussion

To our knowledge, this is the first study to demonstrate a significant association between the presence of PD diagnosed by periodontal examination and PAT volume as assessed with cardiac CT. In the present study, patients with PD, as compared with those without PD, showed significantly higher C-reactive protein and triglyceride levels, greater PAT volume, and lower CT density of PAT. Furthermore, PD was significantly associated with large-PAT volume independent of body weight and hypertension.

4.1. Pericardial fat in patients with cardiovascular disease

Pericardial fat plays a critical role in the homeostasis of a healthy myocardial state by serving as a local source of free fatty acids as metabolic fuel and by providing buffering capacity for excess substrates to prevent lipotoxicity [20]. However, previous studies have shown that excessive pericardial fat could facilitate the development of CVD [4,11]. Expansion of pericardial fat accompanied by obesity may be associated with similar biochemical consequences to those of visceral adipose tissue expansion and hepatic steatosis, including release of tumor necrosis factor-α, interleukin-6 and -1β, and lower adiponectin, potentially independent of BMI [7]. Therefore, these proinflammatory cytokines have been associated with the progression of coronary atherosclerosis, myocardial ischemia, arrhythmia disease, and future cardiovascular events.

In general, there are two types of adipose tissues, brown adipose tissue (BAT) and white adipose tissue (WAT). BAT is a thermogenic organ that expresses unique uncoupling protein 1 (UCP1) on its mitochondrial membrane and is commonly found in young mammals and rodents. The primary function of BAT is to activate the circumvention of ATP production and dissipate chemical energy as heat [21]. In contrast, WAT, as an inflammatory fat deposit with lower CT attenuation than the anti-inflammatory BAT, is related to the atherosclerosis pathway [22]. A previous study showed that the serum level of plaque inflammatory markers and the presence of coronary calcium and major adverse cardiac event (MACE) were associated with increased epicardial adipose tissue volume and lower epicardial adipose density [6]. In the present study, pericardial fat volume, including epicardial fat, was inversely correlated with pericardial fat density (Fig. 2). These findings indicate that lower PAT density is related to greater PAT volume, suggesting that the presence of white PAT is linked to large-PAT volume, which might lead to adverse cardiovascular events.

4.2. Periodontal disease and cardiovascular disease

Periodontal disease is a chronic infectious disease characterized by inflammatory changes in periodontal tissue [12]. PD is highly prevalent and affects approximately 750 million people world-wide [23]. Cardiovascular disease (CVD) is the leading cause of death globally, taking an estimated 17.9 million lives each year. Based on the National Health and Nutrition Examination Survey data, the prevalence in adults of CVD

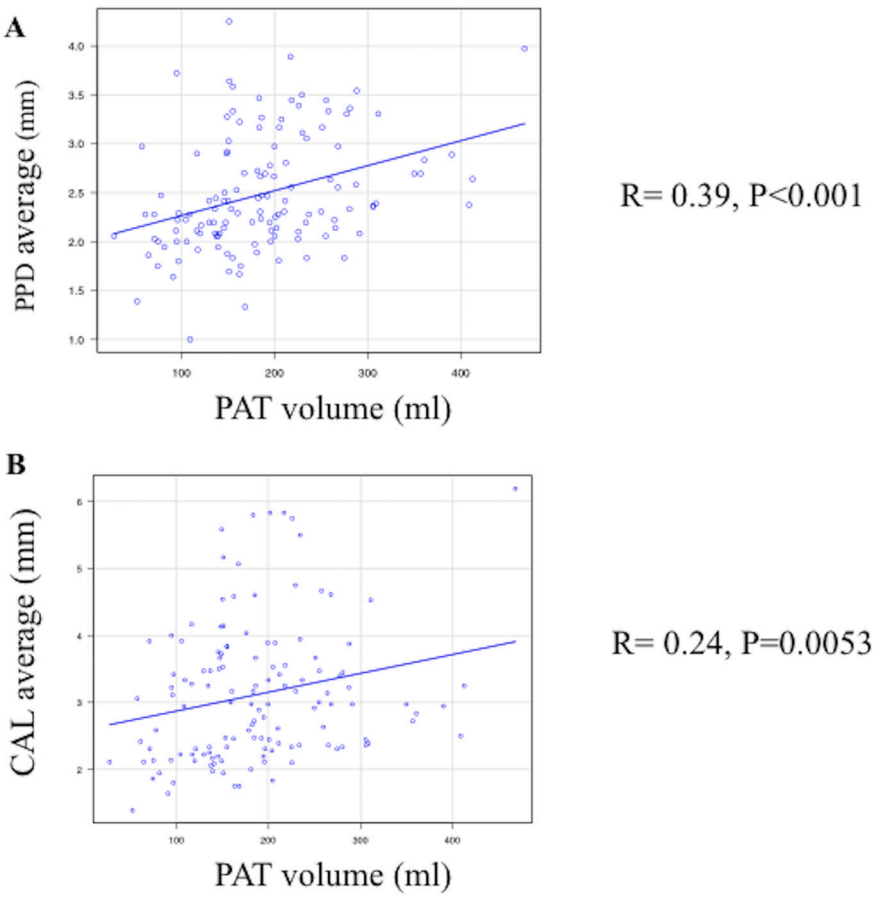

Fig. 3. Linear correlation between PAT volume and CAL average and PPD average
Scatter plot showing linear relationships between the PAT volume and (A) CAL average and (B) PPD average. Significant associations were found for both ($P < 0.01$ for both).
Abbreviations: CAL, clinical attachment level; PAT, pericardial adipose tissue; PPD, probing pocket depth.

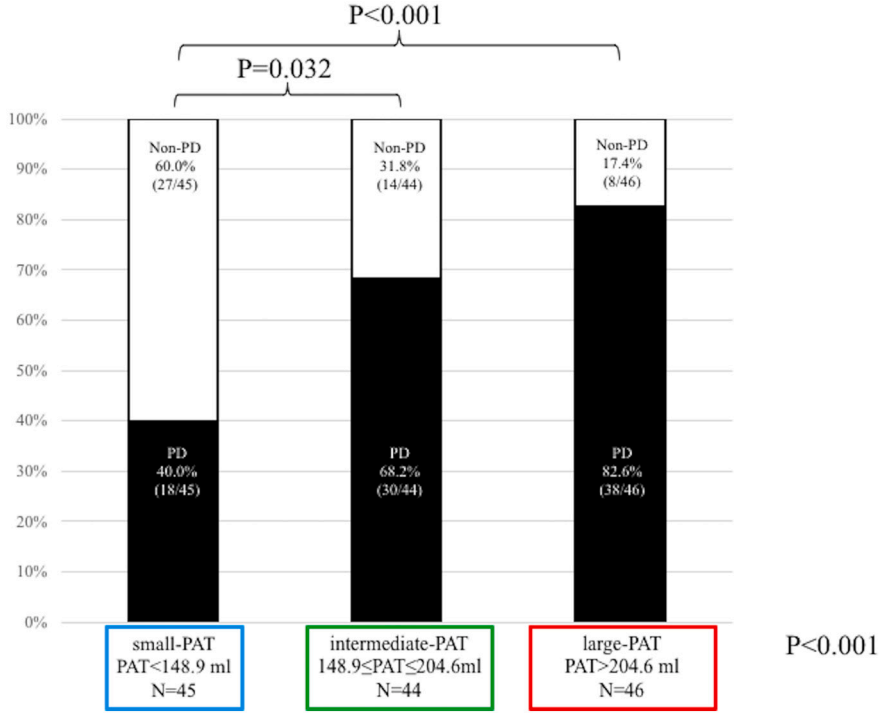

Fig. 4. Frequency of PD stratified by PAT tertile
Abbreviations: PAT, pericardial adipose tissue; PD, periodontal disease.

Table 4
Univariate and multivariate analysis predictions for large-PAT volume.

	Univariate analysis			Multivariate analysis		
	OR	95 % CI	P-value	*OR*	95 % CI	P-value
Age (y)	0.99	0.97–1.03	0.83	–	–	–
Male	6.24	1.78–21.9	0.004	2.85	0.71–11.5	0.14
Body weight (kg)	1.11	1.06–1.16	<0.001	1.12	1.06–1.17	<0.001
Diabetes mellitus, n	1.15	0.55–2.42	0.71	–	–	–
Hypertension, n	2.93	1.26–6.79	0.012	3.97	1.29–12.3	0.017
Dyslipidemia, n	1.59	0.77–3.28	0.21	–	–	–
Triglyceride, mg/dl	1.00	1,00–1.01	0.027	1.00	0.99–1.01	0.95
Past smoker, n	1.51	0.69–3.34	0.30	–	–	–
Arrhythmia disease, n	1.33	0.56–3.14	0.51	–	–	–
EF, %	1.02	0.99–1.05	0.20	–	–	–
Periodontal disease, n	4.06	1.70–9.67	<0.001	4.18	1.46–12.0	0.0078
BoP, n	1.37	0.57–3.30	0.48	–	–	–
Residual teeth, n	1.01	0.97–1.06	0.52	–	–	–
Dental caries, n	0.72	0.35–1.48	0.37	–	–	–

BoP indicates bleeding on probing; and EF, ejection fraction.

including coronary artery disease, heart failure, stroke, and hypertension is 49.2 %; this rate increases with age in both males and females [24]. Several studies have revealed an association between PD and the development of CVD in large cohort studies [13,16]. PD leads to both a local and systemic inflammatory and immune response, which increases circulating inflammatory markers such as white blood cells, C-reactive protein, and inflammatory cytokines including tumor necrosis factor-α, and interleukin-6 and -1β [25]. These systemic inflammatory or immune responses to PD may initiate atherosclerotic changes in the arteries which may further cause cardiovascular disease. In fact, our group recently reported that the presence of PD at the time of percutaneous coronary intervention was associated with an increased risk of MACE in coronary artery disease (CAD) patients who were treated with drug-eluting stent (DES) in *de novo* lesions [17].

4.3. Association between periodontal disease and pericardial fat

In the present study, patients with PD recorded a greater amount of PAT with lower CT attenuation when compared with those without PD. Consistently, the prevalence of PD was higher in patients showing a large-PAT volume on cardiac CT when compared with those with a small-PAT volume, and PD was an independent predictor of a large-PAT volume after adjustment for comorbidity. Thus, the present study notably demonstrated a significant association between PD and pericardial fat. Although the causal relationship between PD and large-PAT volume remains unclear, both PD and greater pericardial fat are reported to be closely associated with systemic inflammatory status. Previous studies have demonstrated that inflammation, oxidative stress, and visceral fat volume predispose to cardiovascular disease [26]. Moreover, some studies suggest that PAT, a type of visceral fat tissue, is associated with inflammation and oxidative stress [27]. Recently, Iwashita et al. showed that the combination of obesity and PD amplified inflammation to levels that affect the whole body through the adipose tissue [28]. In addition, Hatasa et al. reported that endotoxemia by *Porphyromonas gingivalis (Pg)*, which is considered to be a primary factor in PD, potentially affects obesity by disrupting BAT function [29]. These findings suggest the following potential mechanism of the association: PD (local inflammation of the periodontal tissue) induces systemic inflammation [30], which may further facilitate the accumulation of atherogenic, white pericardial adipose tissue (as the patients with PD in the present study showed greater PAT volume and lower CT_{PAT} on CT), and may directly affect the endocrine function in BAT. Our results may support the significant clinical impact of PD on the development of CAD through the potential mechanisms of systemic inflammation. Considering those results, PD may potentially be an identifiable, modifiable, but ignored factor of progressive CAD. Further studies are warranted to prove the impact of periodontal interventions, such as continuous oral health care, on the reduction of PAT and further reduction of CAD.

4.4. Study limitations

The results of the present study should be interpreted with consideration of some limitations. First, this was a retrospective study and thus has inherent limitations. Second, although care was taken to match the measurement of pericardial fat in the CTCA, small differences in location may have occurred in some cases. Coronary calcification, which was the hallmark of coronary atherosclerosis, was not determined due to previously implanted metallic stents in some cases. Third, clinical long-term outcomes were not evaluated. No data on clinical outcomes were obtained to assess the clinical value of the PAT volume. Fourth, obesity represented by body weight or body mass index might be a confounding factor between pericardial fat and presence of PD. Fifth, we did not measure the value of inflammatory cytokines and adipokines, which are related to both the state of PD and the progression of pericardial fat. Finally, if a participant has been regularly seeing a dentist and maintaining good dental hygiene, this may impact results.

5. Conclusions

Pericardial fat volume was significantly greater in patients with PD as compared with those without PD among patients admitted to hospital with cardiovascular disease. Because both PD and pericardial fat are associated with cardiovascular disease, our results may corroborate the clinical impact of PD on the development and progression of CAD.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ahjo.2023.100298.

Ethical statement for solid state ionics

1) This material is the authors' own original work, which has not been previously published elsewhere.
2) The paper is not currently being considered for publication elsewhere.
3) The paper reflects the authors' own research and analysis in a truthful and complete manner.
4) The paper properly credits the meaningful contributions of co-authors and co-researchers.
5) The results are appropriately placed in the context of prior and existing research.
6) All sources used are properly disclosed (correct citation). Literally copying of text must be indicated as such by using quotation marks and giving proper reference.
7) All authors have been personally and actively involved in substantial work leading to the paper, and will take public responsibility for its content.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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