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The influence of habitual tooth brushing frequency on individuals diagnosed with coronary artery disease

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Coronary artery disease (CAD) is a prevalent and high-mortality condition globally. The awareness regarding adequate oral care in China was insufficient. This study investigates the outcomes of CAD patients in southwest China based on their tooth brushing frequency. A total of 841 CAD patients were selected from a cohort of 32,709 residents. Over a four-year follow-up period, the incidence of three-point major adverse cardiovascular events (3P-MACEs) was evaluated. The results indicated that the hazard ratios (HR) with 95% confidence intervals (CIs) for 3P-MACEs among the three groups of tooth brushing frequency (twice, once, and thrice daily) were: reference, 1.61 (1.09–2.37) ($p = 0.017$), and 0.49 (0.15–1.62) ($p = 0.241$). Patients who brushed their teeth only once a day had a 1.71 (1.18–2.46) times higher risk compared to those who brushed twice or more daily ($p = 0.004$). In conclusion, insufficient tooth brushing frequency appears to be associated with a higher risk of adverse outcomes among CAD patients.

Keywords Tooth brushing frequency, Coronary artery disease, Three-point major adverse cardiovascular events, Southwest China

Coronary artery disease (CAD) is a prevalent chronic condition associated with a high global mortality rate[1–4]. The composite endpoint of three-point major adverse cardiovascular events (3P-MACEs), which includes cardiovascular death, myocardial infarction (MI), or stroke, represents an important primary endpoint for cardiovascular outcome trials[5–7].

Atherosclerosis can lead to the formation of lesions in coronary arteries[8]. The possible pathogenesis of atherosclerosis encompasses vascular endothelial dysfunction, dyslipidemia, inflammatory and immune responses, and plaque rupture[9–13]. In addition to age and gender, nine modifiable risk factors—abnormal lipid profiles, smoking, hypertension, diabetes mellitus (DM), abdominal obesity, psychosocial stressors, inadequate fruit and vegetable intake, excessive alcohol consumption, and insufficient physical activity—are responsible for the majority of CAD cases[14].

Previous studies have indicated that oral hygiene is closely associated with the morbidity and mortality of cardiovascular diseases (CVDs)[15–18]. Some even reported that more frequent tooth brushing could reduce the risk of CVDs effectively[19,20]. Regrettably, Chinese who brushed their teeth twice a day or more only accounted for 36.8%[21]. Besides, a national survey highlighted that individuals' oral health behavior could not match the improvement of knowledge and attitudes in China after decades of oral health education[22]. Although the exact mechanisms linking poor tooth brushing frequency to CVDs are still not fully understood, it was proved that poor oral hygiene may increase cardiovascular risk by triggering systemic inflammation, raising markers like C-reactive protein (CRP) and fibrinogen[23,24], and contributing to endothelial dysfunction through periodontal infections[15].

Nevertheless, the existing literature has inadequately addressed the relationship between tooth brushing frequency and CAD in underdeveloped regions of China. Therefore, our study aimed to evaluate the association between tooth brushing frequency and clinical outcomes among residents diagnosed with CAD in southwest China.

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Materials and methods

Study design

This project is a sub-project of the National Key R&D Program of China (2018YFC1311400), with data collected from 16 districts and counties in Chongqing, southwest China, under the guidance of the Health Commission and the Center for Disease Control and Prevention from year 2018 to 2020[25]. The Cardiovascular Department of the First Affiliated Hospital of Chongqing Medical University conducted a comprehensive cross-sectional survey of community residents through stratified random sampling, followed by a retrospective follow-up survey on individuals diagnosed with CAD during the initial investigation[26].

During the baseline data collection, investigators consisted of healthcare workers from local healthcare facilities. The survey methodology predominantly utilized standardized questionnaires administered through face-to-face interviews and telephone conversations (refer to Supplementary material 1)[25,26]. To assess the overall stability of living conditions, participants were requested to provide information regarding their daily habitual lifestyles over the past 5 years[26,27]. They were also instructed to fast for a minimum of 7 h prior to serum blood lipid and glucose tests[26], with all requisite testing equipment supplied by community medical facilities.

The follow-up procedures were conducted by a trained research team, and the medical records of the participants were obtained from healthcare providers to serve as confirmation sources. Data entry into the study system was performed by dedicated data entry clerks and subjected to stratified sampling checks to ensure authenticity and reliability.

In this initial cross-sectional study, a total of 32,709 residents aged 18 years and older were screened[26]. Among these, 1124 individuals were diagnosed with CAD, defined as having at least one coronary artery with stenosis ≥ 50%, as determined by percutaneous coronary angiography or computed tomography angiography[28], at the time of the survey. 13 subjects were excluded from the analysis due to inaccurate or missing key data. During the observational follow-up period from year 2018 to 2023, 39 participants were excluded due to alterations in their habitual tooth brushing frequency. Additionally, 123 participants were lost to follow-up, 62 declined to continue participating in the study, and 46 died from causes unrelated to CAD or cardiovascular diseases. As a result, a total of 841 CAD patients remained in the study (Fig. 1).

The tooth brushing frequency refers to the average daily habitual tooth brushing times over the past 5 years[29]. CAD residents were categorized into three groups: once, twice, and thrice, based on the distribution characteristics of the data. The primary endpoint was the composite of 3P-MACEs[5].

This study was approved by the ethics committee of the First Affiliated Hospital of Chongqing Medical University. All participants agreed on the study content and signed informed consent.

Definition of terms

The key demographics and lifestyle factors in this study were defined as follows[26,30]. Solitary living was characterized by an individual residing an average of 26 or more days per month without companionship. Well-educated referred to an individual who had completed at least a high school education. High income was defined as an average monthly income exceeding 5,000 CNY. The term "CVD family history" indicated the presence of any documented first-degree relative with CVD. Both smoking and alcohol intake involved engaging

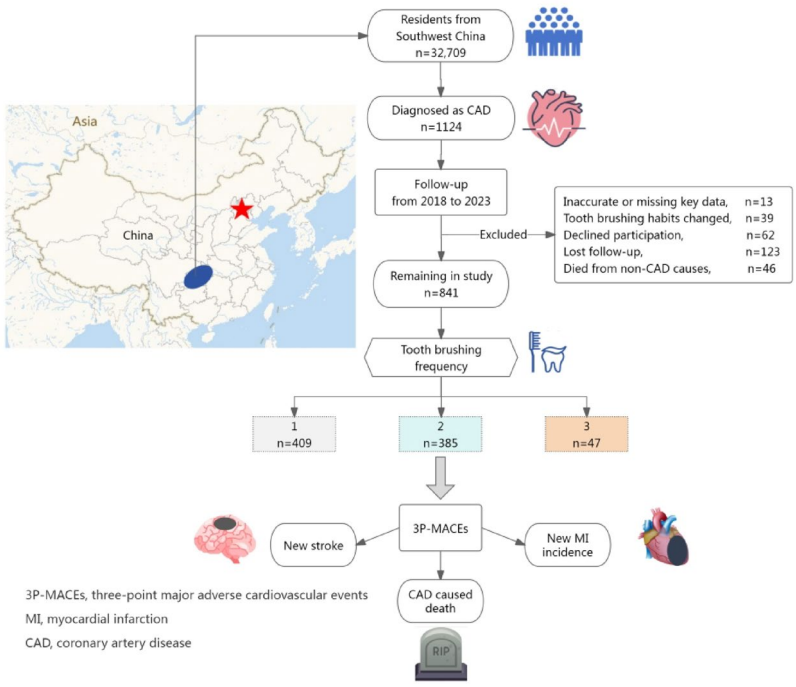


Fig. 1. The study flow chart.

in these habits at least three times weekly. A salty and greasy diet implied favoring salt-rich foods (e.g. pickles, preserved food) or those abundant in fats (e.g. fried dishes). Favors of vegetables, fruits, and yogurt were defined as the weekly inclination to consume these food items for more than five days. Physical inactivity encompassed engaging in labor or exercise for less than 20 h each week.

The diagnosis of the following diseases necessitates confirmation through medical tests or documents conducted at a secondary or tertiary healthcare facility.

Periodontitis is characterized by chronic or acute inflammation of the periodontal tissues. Its clinical manifestations include gingival redness and swelling, bleeding upon probing, periodontal pocket formation, and tooth mobility[31,32], as documented in participants' medical records or observed during oral examinations.

Hypertension was defined when any one of the three criteria was satisfied: (a) the systolic blood pressure (SBP) ≥ 140 mmHg or (b) the diastolic blood pressure (DBP) ≥ 90 mmHg on multiple occasions during periods of calmed rest or (c) under the use of antihypertensive medication[33].

Chinese criteria of weight for adults defined obesity as body mass index (BMI) ≥ 28 kg/m^2[34].

The diagnosis of diabetes mellitus (DM) should follow fasting plasma glucose (FPG) ≥ 7.0 mmol/L, and/or 2 h-post challenge plasma glucose (PG) ≥ 11.1 mmol/L, and/or HbA1c ≥ 48 mmol/mol[35], and/or under hypoglycemic drugs use.

Hyperlipidemia was diagnosed as any of the followings : (a) total cholesterol (TC) > 5.7 mmol/L; (b) triglyceride (TG) > 1.7 mmol/L; (c) low density lipoprotein-C (LDL-C) > 3.37 mmol/L; (d) use of lipid-lowering drugs[36].

Stroke encompassed both ischemic strokes and hemorrhagic strokes, which had been identified through cranial imaging[37].

The diagnosis of MI was made when there was an elevation in serum cardiac markers accompanied by any one of the following: (a) symptoms of myocardial ischemia; (b) new ECG changes; (c) imaging evidence of decreased viable myocardium or abnormal new ventricular wall motion[38].

Peripheral artery disease (PAD) was defined as a kind of atherosclerotic disease, affecting the aorta or arteries in lower extremities[39].

Atrial fibrillation was detected based on electrocardiogram[40].

CAD-caused mortality referred to the occurrence of death or sudden death resulting from CAD or its complications[41,42], as confirmed or inferred by medical documentation, while excluding the possibility of other underlying diseases or accidents.

Data analysis

Continuous variables with a normal distribution were expressed as mean ± standard deviation (SD), and one-way analysis of variance (ANOVA) was employed to compare the differences between groups in cases where the variances exhibited homogeneity. Otherwise, the median and inter quartile range (25%-75%) were reported, and the Kruskal–Wallis test was utilized for comparing group differences. Categorical variables were presented as numbers with percentages (n%), and comparison between groups was conducted using Pearson χ^2 test.

Considering that the endpoint event of this study is time-dependent, Kaplan–Meier (KM) plots including log-rank tests were utilized to assess the relationship between tooth brushing frequency and outcome events across the three groups. Subsequently, Cox regression analysis was conducted to examine the impact of tooth brushing frequency on outcome events, after adjusting for recognized prognostic factors. In addition, hazard ratio (HR) values with 95% confidence intervals (CI) and p values were calculated. For daily tooth brushing frequency, the group of 2 times per day served as the reference.

Data analyses were performed on IBM SPSS Statistics, version 28 (IBM Corporation, Armonk, NY, USA) and diagrams were generated on Prism version 9. Statistical significance was set as p value < 0.05 (two-sided).

Results

The prevalence of CAD in this population was 3.4% (1124/32,709). We recruited 841 CAD residents, 59.7% of them were female, and the average age of the participants was 69.2 ± 8.2 years old (ranging from 27–92 years). As displayed in Table 1, the distribution of habitual daily brushing frequency (1, 2, 3) was 48.6%, 45.8%, and 5.6% respectively, with no residents reporting zero or more than four times of tooth brushing.

As presented in Table 2, CAD participants who brushed their teeth once a day exhibited lower levels of education and income, higher proportions of consuming a salty diet, more likely to experience periodontitis and tooth loss, elevated levels of total cholesterol (TC) and low-density lipoprotein cholesterol (LDL-C), but lower levels of high-density lipoprotein cholesterol (HDL-C). On the other hand, individuals who brushed their teeth twice daily or more had a reduced likelihood of having a CVD family history, and showed higher preferences for

Tooth brushing frequency	n (%)
0	0 (0.0)
1	409 (48.6)
2	385 (45.8)
3	47 (5.6)
≥ 4	0 (0.0)
Total	841 (100.0)

Table 1. Distribution of tooth brushing frequency.

Characteristics	Overall (n = 841)	Tooth brushing frequency per day			p value
		1 time (n = 409)	2 times (n = 385)	3 times (n = 47)	
Demographics					
Enrollment age, yrs	69.20 ± 8.24	69.84 ± 7.28	68.50 ± 9.22	69.28 ± 7.25	0.073
Female gender, n%	502 (59.7)	256 (62.6)	217 (56.4)	29 (61.7)	0.194
Solitary living, n%	86 (10.2)	46 (11.2)	32 (8.3)	8 (17.0)	0.113
Well educated, n%	126 (15.0)	25 (6.1)	91 (23.6)	10 (21.2)	< 0.001
High income, n%	61 (7.3)	10 (2.4)	47 (12.2)	4 (8.5)	< 0.001
CVD family history, n%	109 (13.0)	79 (19.3)	27 (7.0)	3 (6.4)	< 0.001
Lifestyles					
Smoking, n%	120 (14.3)	70 (17.1)	43 (11.1)	7 (14.8)	0.057
Alcohol intake, n%	97 (11.5)	52 (12.7)	39 (10.1)	6 (12.7)	0.504
Salty diet, n%	176 (20.9)	107 (26.2)	62 (16.1)	7 (14.8)	0.001
Greasy diet, n%	73 (8.7)	29 (7.0)	41 (10.6)	3 (6.3)	0.174
Favor vegetables, n%	805 (95.7)	385 (94.1)	380 (98.7)	40 (85.1)	< 0.001
Favor fruits, n%	386 (54.1)	132 (32.3)	231 (60.0)	23 (48.9)	< 0.001
Favor yogurt, n%	126 (15.0)	19 (4.6)	100 (25.9)	7 (14.8)	< 0.001
Physical inactivity, n%	264 (31.4)	137 (33.5)	118 (30.6)	9 (19.1)	0.122
Oral health					
Morning tooth brushing, n%	663 (78.8)	245 (59.9)	371 (96.4)	47 (100.0)	< 0.001
Night tooth brushing, n%	589 (70.0)	164 (40.1)	378 (98.2)	47 (100.0)	< 0.001
Periodontitis, n%[a]	249 (34.4)	180 (51.7)	64 (19.2)	5 (11.6)	< 0.001
Tooth loss, n%[a]	99 (13.7)	62 (17.8)	34 (10.2)	3 (7.3)	0.007
Dentures, n%[a]	186 (26.1)	88 (25.6)	90 (27.2)	8 (20.5)	0.643
Physical examinations					
Height, cm	156.49 ± 8.79	155.06 ± 8.42	158.20 ± 8.75	154.97 ± 9.95	< 0.001
Weight, kg	61.21 ± 9.97	59.57 ± 9.97	63.20 ± 9.87	59.17 ± 7.63	< 0.001
BMI, kg/m^2	25.00 ± 3.71	24.82 ± 4.05	25.24 ± 3.45	24.66 ± 2.52	0.073
Heart rate, bpm	74.17 ± 11.68	74.84 ± 11.91	73.47 ± 11.44	74.13 ± 11.52	0.175
SBP, mmHg	139.51 ± 15.86	139.73 ± 16.57	139.38 ± 15.24	138.60 ± 14.76	0.883
DBP, mmHg	81.45 ± 10.68	81.93 ± 10.76	81.16 ± 10.64	79.64 ± 10.20	0.299
Serum biochemical tests					
TG, mmol/L	1.39 (1.03–2.10)	1.36 (0.99–2.06)	1.41 (1.05–2.10)	1.31 (1.03–1.62)	0.175
TC, mmol/L	4.77 (4.07–5.49)	4.90 (4.18–5.60)	4.52 (3.94–5.31)	4.88 (4.16–5.60)	0.001
HDL-C, mmol/L	1.42 (1.17–1.71)	1.40 (1.16–1.71)	1.45 (1.17–1.70)	1.61 (1.25–1.85)	0.038
LDL-C, mmol/L	2.33 (1.89–3.00)	2.49 (1.96–3.04)	2.22 (1.82–2.93)	2.21 (1.69–2.93)	0.009
Fasting glucose, mmol/L	5.92 ± 2.08	5.91 ± 2.33	5.95 ± 1.83	5.90 ± 1.69	0.293

Table 2. Baseline characteristics of CAD residents grouped by tooth brushing frequency. *CAD* coronary artery disease, *CVD* cardiovascular disease, *BMI* body mass index, *SBP* systolic blood pressure, *DBP* diastolic blood pressure, *TG* triglycerides, *TC* total cholesterol, *HDL-C* high density lipoprotein cholesterol, *LDL-C* low density lipoprotein cholesterol. [a]Data loss of 117 for periodontitis, 119 for tooth loss, and 127 for dentures.

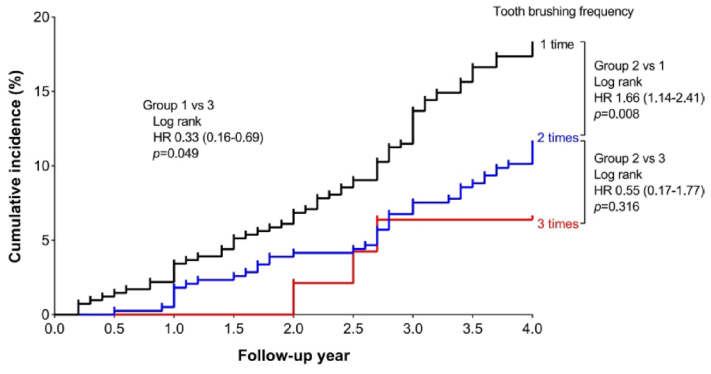
vegetables, fruits, and yogurt, and tended to brush their teeth both in the morning and at night. They also had greater height and weight. However, among the three groups, gender, solitary living, smoking habits, alcohol consumption, greasy diet intake, and physical inactivity were comparable. Additionally, they all had similar ages, body mass index (BMI), heart rate values, blood pressure readings, triglyceride levels, and fasting glucose concentrations.

According to Table 3, at baseline, participants with CAD who brushed their teeth once a day had a lower prevalence of stroke and a lower proportion of lipid-lowering drugs use. Apart from this, there were no significant differences in comorbidity and medication use among the three groups at baseline. However, during follow-up, individuals who brushed their teeth once a day had the highest rate of 3P-MACEs (18.1%), new stroke (5.4%) and CAD-related death (7.8%), and a lower proportion of lipid-lowering drugs use. There were no notable differences in the prevalence of new MI or the use of anti-hypertensive, anti-hyperglycemic, and anti-thrombotic drugs among the three groups. Over the four-year follow-up period, 121 cases (14.4%) within the general cohort were found to suffer from 3P-MACEs, with 31 new stroke cases (3.7%), 68 new MI cases (8.1%), and 42 deaths (5.0%) attributed to CAD.

The KM curves in Fig. 2 revealed that compared to a daily tooth brushing frequency of 2 times, individuals who brushed their teeth only once had a significantly higher probability of 3P-MACEs, with an HR of 1.66 (95% CI: (1.14–2.41) (log rank $p = 0.008$).

Items	Overall (n = 841)	Tooth brushing frequency per day			*p* value
		1 time (n = 409)	2 times (n = 385)	3 times (n = 47)	
Comorbidity at baseline					
Hypertension, n%	665 (79.1)	314 (76.8)	315 (81.8)	36 (76.5)	0.199
Hyperlipidemia, n%	468 (55.6)	240 (58.7)	208 (54.0)	20 (42.5)	0.075
DM, n%	179 (21.3)	80 (19.6)	91 (23.6)	8 (17.0)	0.286
Obesity, n%	151 (18.0)	76 (18.6)	69 (17.9)	6 (12.7)	0.617
Stroke, n%	94 (11.2)	33 (8.1)	47 (12.2)	14 (29.7)	< 0.001
Atrial fibrillation, n%	42 (5.0)	24 (5.9)	14 (3.6)	4 (8.5)	0.185
PAD, n%	16 (1.9)	5 (1.2)	10 (2.5)	1 (2.1)	0.364
Medication use at baseline					
Anti-PLT, n%	102 (12.1)	52 (12.7)	42 (10.9)	8 (17.0)	0.423
Anticoagulants, n%	14 (1.7)	6 (1.5)	6 (1.5)	2 (4.2)	0.359
Anti-hypertensive drugs, n%	526 (62.5)	255 (62.3)	246 (63.8)	25 (53.1)	0.357
Anti-hyperglycemic drugs, n%	146 (17.4)	70 (17.1)	69 (17.9)	7 (14.8)	0.860
Lipid-lowering drugs, n%	141 (16.8)	50 (12.2)	76 (19.7)	15 (31.9)	< 0.001
Medication use at follow-up					
Anti-PLT, n%	188 (22.4)	79 (19.3)	95 (24.6)	14 (29.7)	0.088
Anticoagulants, n%	21 (2.5)	9 (2.2)	10 (2.5)	2 (4.2)	0.684
Anti-hypertensive drugs, n%	550 (65.4)	262 (64.1)	261 (67.8)	27 (57.5)	0.271
Anti-hyperglycemic drugs, n%	163 (19.4)	73 (17.9)	83 (21.6)	7 (14.9)	0.303
Lipid-lowering drugs, n%	196 (23.3)	74 (18.1)	107 (27.7)	15 (31.9)	0.002
Outcomes at follow-up					
Years of follow up, yrs	4.00 (4.00–4.00)	4.00 (4.00–4.00)	4.00 (4.00–4.00)	4.00 (4.00–4.00)	0.129
3P-MACEs, n%	121 (14.4)	74 (18.1)	44 (11.4)	3 (6.4)	0.008
New stroke, n%	31 (3.7)	22 (5.4)	8 (2.1)	1 (2.1)	0.040
New MI, n%	68 (8.1)	35 (8.6)	30 (7.7)	3 (6.3)	0.839
CAD-caused death, n%	42 (5.0)	32 (7.8)	8 (2.0)	2 (4.3)	< 0.001

Table 3. Comorbidity, medication, and main outcomes among different groups. *DM* diabetes mellitus, *PAD* peripheral arterial disease, *PLT* platelet, *3P-MACEs* three-point major adverse cardiovascular events, *MI* myocardial infarction, *CAD* coronary artery disease.



Tooth brushing	Cumulative number of 3P-MACEs cases, n(%)								
1 time, n=409	0(0.0)	31(7.5)	36(8.8)	41(10.0)	45(11.0)	55(13.4)	66(16.1)	71(17.3)	74(18.0)
2 times, n=385	0(0.0)	10(2.5)	13(3.3)	19(4.9)	19(4.9)	29(7.5)	33(8.5)	39(10.1)	44(14.4)
3 times, n=47	0(0.0)	0(0.0)	0(0.0)	0(0.0)	1(2.1)	3(6.3)	3(6.3)	3(6.3)	3(6.3)

Fig. 2. Comparison of the 3P-MACEs incidence across the three groups by Kaplan-Meier survival curves.

After multivariate adjustments, Cox regression analysis presented in Fig. 3 revealed the HR with 95% CIs among the three groups of tooth brushing frequency (2, 1, and 3 times per day), for 3P-MACEs were: reference, 1.61 (1.09–2.37) ($p = 0.017$), and 0.49 (0.15–1.62) ($p = 0.241$) (seen in Table 4); for new stroke: reference, 2.51 (1.08–5.80) $p = 0.032$), and 1.09 (0.13–8.97) $p = 0.935$) (Supplementary Table 1); for new MI: reference, 1.05 (0.63–1.76) ($p = 0.852$), and 0.70 (0.20–2.46) ($p = 0.580$) (Supplementary Table 2); for CAD-related death: reference, 3.83 (1.69–8.66) ($p = 0.001$), and 1.37 (0.25–7.46) $p = 0.714$) (Supplementary Table 3).

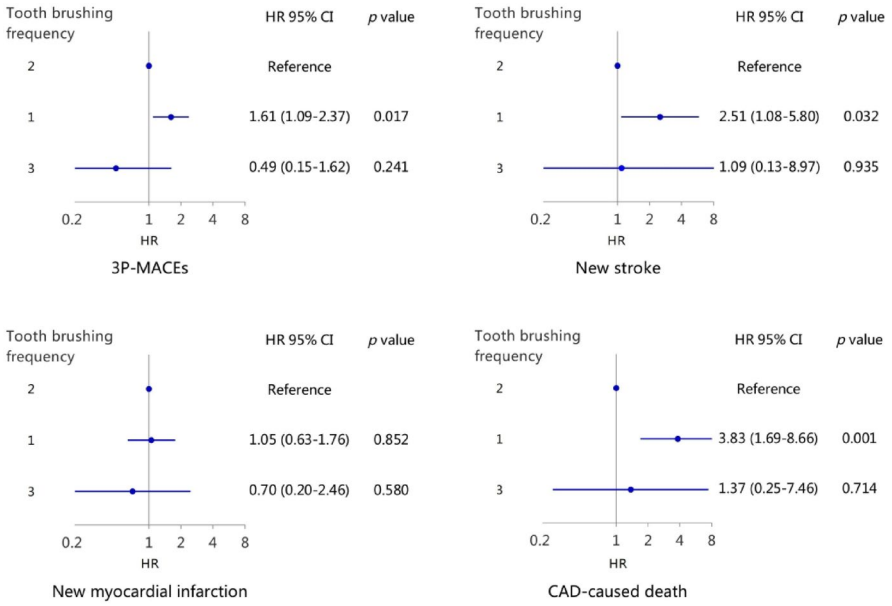


Fig. 3. Association between tooth brushing frequency with 3P-MACEs and its components by multivariate Cox regression analysis.

	Univariate analysis		Multivariate analysis[a]	
Variables	**HR (95% CI)**	***p* value**	**HR (95% CI)**	***p* value**
Enrollment age[b]	1.04 (1.01–1.06)	0.003	1.04 (1.02–1.07)	0.002
Female gender	0.55 (0.38–0.78)	< 0.001	0.57 (0.37–0.87)	0.009
CVD family history	1.70 (1.14–2.53)	0.010	1.32 (0.86–2.03)	0.201
Salty diet	1.64 (1.11–2.43)	0.013	1.53 (1.01–2.33)	0.049
Favor vegetables	0.60 (0.29–1.22)	0.156	0.41 (0.19–0.89)	0.024
Physical inactivity	1.23 (0.85–1.78)	0.277	1.24 (0.83–1.86)	0.284
Smoking	1.91 (1.25–2.91)	0.003	1.41 (0.81–2.45)	0.229
Alcohol intake	1.61 (1.00–2.60)	0.052	1.41 (0.81–2.45)	0.229
Hypertension	1.56 (0.95–2.57)	0.082	1.42 (0.86–2.37)	0.173
Hyperlipidemia	1.10 (0.76–1.57)	0.615	0.99 (0.68–1.43)	0.942
DM	2.38 (1.64–3.44)	< 0.001	2.73 (1.84–4.06)	< 0.001
Obesity	1.10 (0.70–1.73)	0.686	1.06 (0.66–1.69)	0.816
Anti-PLT	1.41 (0.86–2.30)	0.168	1.08 (0.64–1.82)	0.760
Lipid-lowering drugs	1.47 (0.96–2.25)	0.079	Excluded[c]	
Tooth brushing frequency				
2 times	Reference		Reference	
1 time	1.66 (1.14–2.41)	0.008	1.61 (1.09–2.37)	0.017
3 times	0.55 (0.17–1.77)	0.316	0.49 (0.15–1.62)	0.241

Table 4. Univariate and multivariate Cox analysis for the incidence of 3P-MACEs. *3P-MACEs* three-point major adverse cardiovascular events, *CAD* coronary artery disease, *HR* hazard ratio, *CI* confidence interval, *CVD* cardiovascular disease, *DM* diabetes mellitus, *PLT* platelet. [a]Multivariate analysis was adjusted by enrollment age, female gender, CVD family history, salty diet, favor vegetables, physical inactivity, smoking, alcohol intake, hypertension, hyperlipidemia, DM, obesity, anti-PLT, and tooth brushing frequency. [b]Enrollment age served as continuous variables. [c]Excluded as a confounder of hyperlipidemia.

After being divided into two groups (1, ≥ 2) based on tooth brushing frequency, individuals who brushed their teeth once a day had an increased risk of 3P-MACEs in the majority of subgroups, with an overall HR of 1.71 (1.18–2.46) ($p = 0.004$) (Fig. 4).

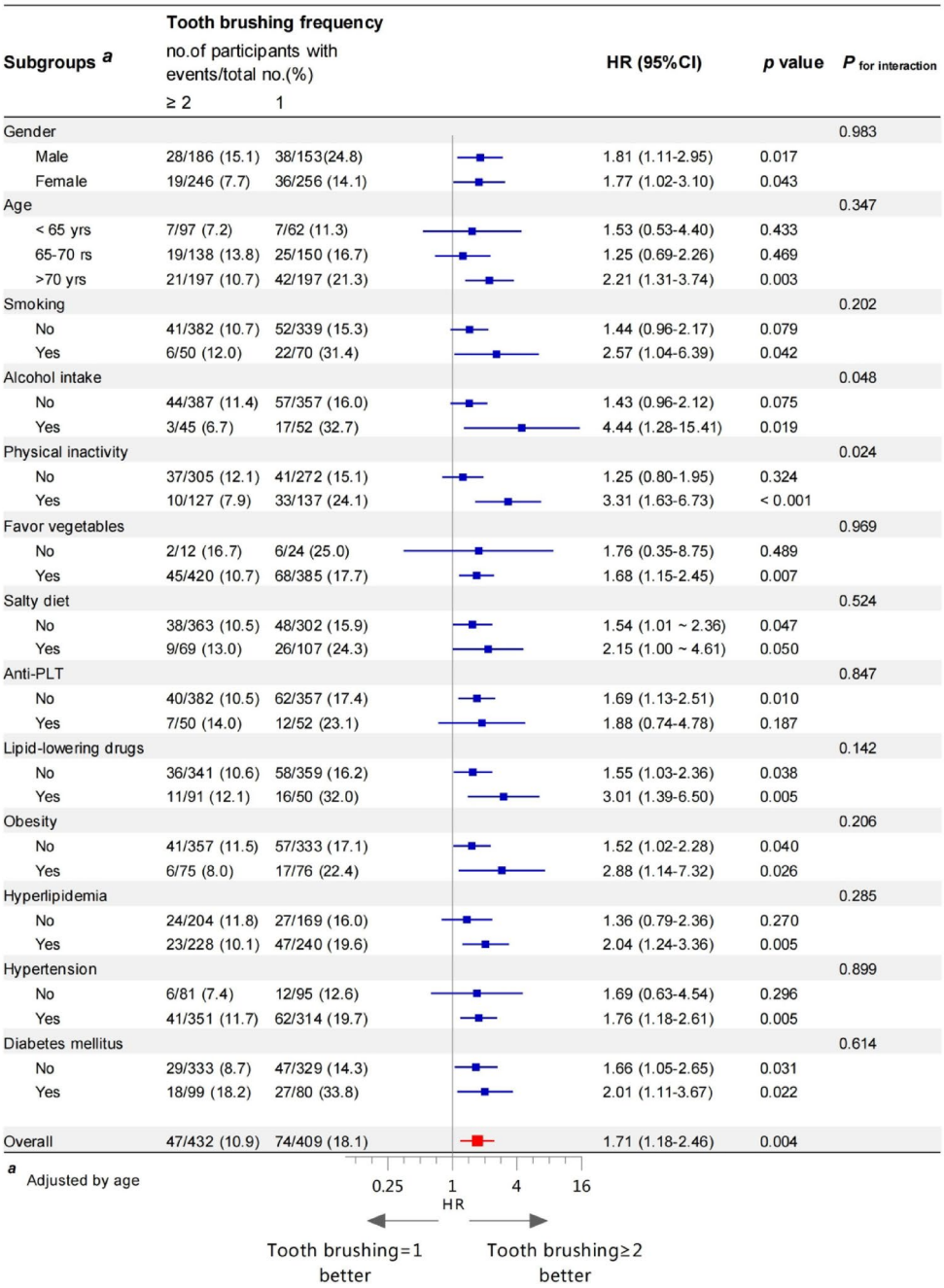


Fig. 4. Subgroups analysis (adjusted by age) for 3P-MACEs between the two groups.

Discussion

The present study was a retrospective analysis conducted on residents diagnosed with CAD in southwest China. The key findings were: (1) Only 51.4% of the participants reported brushing their teeth twice or more daily. (2) The prevalence of CAD among the general population was found to be 3.4%. Additionally, over a four-year follow-up period, the incidence rates of 3P-MACEs, new stroke, new MI, and CAD-caused mortality were observed to be 14.4%, 3.7%, 8.1%, and 5.0%, respectively. (3) Inadequate tooth brushing frequency may potentially increase the risk of 3P-MACEs.

Oral health promotion has attracted increased attention from the public in China[43]. However, approximately 19.3% of Chinese suffered from severe periodontal diseases in 2019[44]. Our study found that the prevalence of periodontitis was 34.4%, and 13.7% of the residents who had missing teeth. This was only a rough investigation and analysis, the actual prevalence rate could be definitely higher than this, as some residents had never visited an oral medical institution. Besides, only less than 20% of Chinese adults had a good understanding of periodontal diseases, which revealed that the Chinese population's cognition of oral health has not significantly developed over the years[45]. From another perspective, public health strategies regarding periodontal health

remained insufficient[45]. Until 2021, in the primary care services of the public health department, the procedures for diagnosis and management of periodontal diseases were incomplete[46]. Curative and rehabilitation oral health care was still not covered in health benefits packages for Chinese citizens, only routine and preventive oral care was provided[46].

It was recommended that tooth brushing more than twice per day was significant for preventing caries[47], before bedtime and on other occasions[48,49]. According to the Adult Oral Survey 2021 in the UK, approximately 77% of adults (16 years and over) reported brushing their teeth at least twice daily, while 20% indicated they brushed once per day. Only 2% stated they brushed their teeth less frequently than once a day[50]. In the last 5 years, studies about Chinese citizens' oral care, oral hygiene, and tooth brushing habits were limited. Therefore, according to newly published data from the 4th national oral health epidemiology survey in 2016, oral diseases remained highly prevalent in China[43]. Nevertheless, access to specialized dental care was limited for most citizens, and many individuals found it unaffordable because of restricted insurance coverage[43]. Although the study population was limited, our research observed that 78.8% of residents brushed their teeth in the morning, whereas 70.0% did so in the evening. Notably, nearly half of the respondents did not meet the recommended frequency for tooth brushing. This phenomenon exhibited residents' neglect of oral health to some degree.

The incidence of CAD has rapidly increased over the past two decades, and the estimated number of CAD patients in China for the year 2022 was 11.39 million[51], making it the second leading cause of death[52–54]. Consequently, this has imposed a substantial economic burden on society[55,56]. The main findings of our study align with the results documented in the existing literature, that a reduced daily frequency of tooth brushing may increase adverse cardiovascular outcomes[29,57–61].

For instance, Oliveira et al. reported that CAD had the highest proportion of cardiovascular events caused by poor oral hygiene, they reported an HR for fatal CVD of 2.40 (1.50–4.00) for tooth brushing less than once a day within 8.1 follow-up years[23]. In addition, research by Zhuang et al.[24] and Zhou et al.[57] discovered that less tooth brushing frequency was associated with an increased risk of all-cause mortality. Similarly, Matsui et al.'s research proved that insufficient frequency and short duration of tooth brushing (< twice/day and < 2 min/procedure) were associated with a higher risk of major adverse cardiovascular events including acute MI, with an HR of 3.06 (1.24–7.63)[15]. A prior study by Chang et al. analyzed 206,602 individuals indicating that frequent tooth brushing (≥ 3 times/day) was associated with a reduced stroke risk (HR: 0.80; 95% CI 0.75–0.85; $p < 0.001$)[58]. Additionally, individuals who brushed their teeth more frequently were reported to have lower 10-year cardiovascular risk[59]. Moreover, a systematic review also highlighted a significant negative correlation between the frequency of tooth brushing and CVD risk[35]. These findings further support the link between poor periodontal health status and an elevated risk of CVD[23].

In contrast, our study, which featured a 4-year follow-up period, demonstrated that CAD participants who brushed their teeth once daily had a significantly higher HR for new stroke events and CAD-related mortality, compared to those who brushed twice daily. Furthermore, those who brushed once daily exhibited an elevated risk of 3P-MACEs.

Conversely, although the group that brushes once daily has the highest incidence of new-onset MI (8.6%), our findings did not reveal that tooth brushing frequency had a remarkable influence on the incidence of new-onset MI among CAD residents. This may be attributed to the fact that our study population exclusively comprised CAD patients from southwest China, with MI cases limited to newly occurring events. Additionally, the CAD patient group may have exhibited a lower propensity to initiate and adhere to anti-platelet and lipid-lowering medications both at baseline and during follow-up after diagnosis. During the follow-up period, the research team may also provide additional medical advice to reduce the likelihood of progression to MI. However, this does not negate the potential benefits of regular oral hygiene behaviors such as tooth brushing.

Owing to the inherent limitations of the research design, it was not feasible to provide a detailed description of the oral hygiene characteristics of the population or to adjust for relevant confounding factors. Individuals with varying tooth brushing frequencies exhibit differences in demographic, social, psychological, economic, and physical conditions. Nevertheless, based on the aforementioned literature and our study findings, multi-factor correction analyses were conducted across different regions and populations, yielding consistent conclusions. Particularly, in our subgroup analysis, most subgroups demonstrated that less frequent tooth brushing was associated with 3P-MACEs, suggesting this was not a random occurrence. Therefore, we posit that reduced frequency of tooth brushing is likely to constitute a significant potential risk factor for adverse cardiovascular events.

The exact physiological mechanisms linking tooth brushing frequency to cardiovascular events are not yet fully understood. Nevertheless, there were researches revealing that insufficient tooth brushing frequency was closely associated with periodontitis[60,61].

In Cho et al.'s study[60], the frequency of tooth brushing made a significant impact on the classification of periodontal conditions. Compared with the healthy group, participants with severe periodontal disease showed a higher incidence of 26% for acute MI (HR: 1.26, 95% CI 1.13–1.42)[60]. During 10 years, acute MI presented more in people with severe periodontal conditions than people with no severe periodontal conditions (healthy or moderate periodontal conditions): 1.0% vs. 0.7%[60].

Current evidence indicates that chronic bacteremia and low-grade systemic inflammation associated with periodontitis may significantly contribute to the development of atherosclerosis and related CVDs[62]. Elevated levels of CRP are strongly correlated with the incidence of cardiovascular metabolic diseases and have adverse effects on individuals with pre-existing cardiovascular conditions[63]. Systemic inflammation or immune responses elicited by periodontal infections can result in increased concentrations of white blood cells, CRP, and pro-inflammatory cytokines, thereby exacerbating the inflammatory state and potentially increasing the risk of cardiovascular events[29,64]. Moreover, periodontal pathogens can directly adhere to endothelial cells and colonize atherosclerotic plaques, leading to plaque instability and possibly triggering thrombotic events

associated with atherosclerosis[64]. Research has demonstrated that enhancing oral hygiene practices can reduce levels of inflammatory markers such as CRP, further inhibiting the role of oral bacteria in driving systemic inflammation[63,65].

Our research indicates that individuals who brush their teeth once daily exhibit a higher prevalence of periodontitis and tooth loss, suggesting suboptimal oral hygiene practices. We hypothesize that these individuals might have elevated levels of inflammatory mediators in their blood, although this could not be confirmed through blood tests in this present study. Furthermore, those with less frequent brushing habits tend to have lower educational attainment and income levels, this demographic is also less likely to engage in healthy lifestyles. Lastly, despite the established protective effects of lipid-lowering drugs against cardiovascular events[66,67], these patients present relatively higher cholesterol levels and lower utilization rates of lipid-lowering medications, thereby diminishing the potential protective benefits. In conclusion, these hypotheses may elucidate the observed association in our study population between less frequent tooth brushing among CAD patients and an increased risk of 3P-MACEs.

Study strengths

We are one of the limited number of studies that have examined the prognosis of CAD residents with varying tooth-brushing habits in Southwest China. Our data sources are robust and the follow-up duration is substantial (4 years). While no direct interventions were implemented, this study has facilitated awareness among residents regarding the significance of proper oral hygiene. Furthermore, it has provided healthcare professionals with valuable insights to assist CAD patients in modifying unhealthy lifestyles.

Limitations

Despite the significant contributions of our research, several limitations should be acknowledged. (1) The study sample, although derived from a large epidemiological dataset, was confined to patients with a definitive diagnosis of CAD in the southwest region of China, resulting in a relatively limited sample size and geographical scope. Consequently, further large-scale, multi-regional studies are warranted to validate our findings. (2) This study adopted a retrospective design rather than a prospective one. Although we endeavored to adjust for confounding factors influencing cardiovascular prognosis based on existing literature, inherent limitations of retrospective studies may still introduce biases. Factors such as the event rate, sample size, and unmeasured covariates could potentially affect the results. (3) Our analysis focused solely on tooth brushing frequency, unable to consider other important aspects such as brushing technique, duration, or quality, nor did it examine the diagnosis and treatment of oral diseases. The absence of this information might introduce bias into our results. Additionally, unlike some other studies that included individuals with zero tooth brushing frequency as a reference group, our study lacked such a cohort due to the nature of our sample. Therefore, future research should aim to address these limitations through carefully designed prospective studies involving diverse populations.

Conclusions

Our study suggests that, among CAD residents in southwest China, a lower tooth brushing frequency (once a day) appeared to an increased risk of 3P-MACEs, new onset stroke, and mortality caused by CAD, however, there is no significant association between tooth brushing frequency and the onset of new MI.

Data availability

The dataset used and analyzed in this study is available from the corresponding author [GL] upon reasonable request.

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Author contributions

G.L designed, conducted, and analyzed the experiments, derived the models, and interpreted the data. R.F.M, R.Y.W, Y.D.L and B.Q.W contributed to the implementation of the study. Z.H.T and T.Q collaborated with G.L in writing the manuscript. B.H and S.X.L provided superior guidance and conducted advanced review for this work. All authors critically reviewed and approved the final version.

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Declarations

Competing interests

The authors declare no competing interests.

Ethical approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki and approved by the ethics committee of the First Affiliated Hospital of Chongqing Medical University. All the participants were informed of the study content and signed informed consent.

Additional information

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