Association Between Periodontitis and Diabetes: Results from the 4th National Oral Health Survey in China (2015–2016)

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Objective: *To evaluate the cross-sectional correlation between severity of periodontitis and diabetes in a representative sample of the Chinese population.*

Methods: *Data of dentate subjects (35- to 44-year-old group [n = 4,409], 55- to 64-year-old group [n = 4,568] and 65- to 74-year-old group [n = 4,218]) were analysed. Self-reported diagnosis of diabetes was based on a face-to-face interview. Periodontal status was defined according to the 2018 classification scheme. Periodontal parameters included bleeding on probing (BOP), probing depth (PD) and attachment loss (AL). Distribution of periodontal status and parameters in diabetic and non-diabetic subjects were calculated. Smoothing plots were illustrated to show the correlation between periodontal parameters/status and diabetes.*

Results: *The frequency of severe periodontitis (Stage III and Stage IV) in diabetic subjects was significantly higher than that in non-diabetic subjects (41.88% vs 30.22%, P < 0.001). The percentages of periodontal parameters of diabetic subjects were significantly higher than those of non-diabetic subjects (57.71% vs 53.12% for BOP, 22.11% vs 16.29% for PD ≥ 4 mm and 2.07% vs 1.22% for PD ≥ 6 mm, respectively). Increased risk of diabetes was observed in subjects with severe periodontitis. Positive associations were found between the percentage of affected teeth with PD ≥ 4/6 mm and diabetes.*

Conclusion: *Severe periodontitis is associated with diabetes in the Chinese population, and highlighted in younger patients.*

Keywords: *diabetes, periodontal status, periodontitis, probing depth, 4th National Oral Health Survey*

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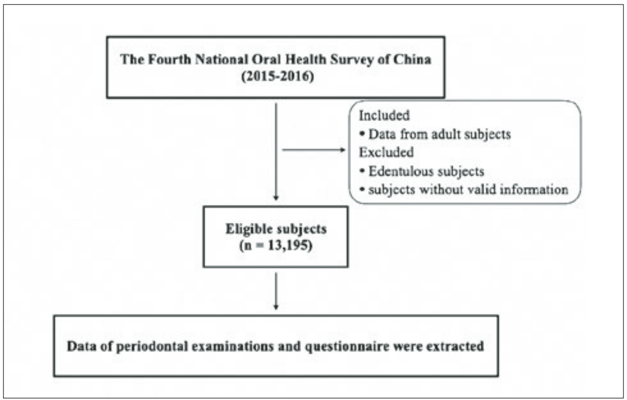

Fig 1 Flowchart of inclusion of subjects and study procedures.

Periodontitis is a chronic infectious-inflammatory disease.[1] The Global Burden of Disease Study conducted in 2021 reported that it was the sixth most prevalent disease globally, with over 1 billion people affected by severe periodontitis and a global age-standardised prevalence of 12.50%.[2] Compared to 1990, there has been an increase in the global total number of prevalent (+99.96%) and incident (+93.56%) severe periodontitis cases.[2] By 2050, it is projected that over 1.56 billion people will be living with severe periodontitis, an increase of 500 million people from 2021 (+44.32%), representing an annual growth rate of 3.06%.[2] The data from the 4th National Oral Health Survey in the Mainland of China showed that almost 90% of Chinese adults suffered from periodontal disease of various severities; > 30% had severe periodontitis.[3] Severe periodontitis is expected to affect 333.44 million people in China by 2050,[2] and has been linked with heightened risk of contracting several systemic diseases and even mortality.[4-6]

Diabetes is a common metabolic disease resulting from a defect in insulin secretion or action, or a combination of both.[7] The number of people with diabetes has risen rapidly in the last several decades from 108 million in 1980 to 422 million in 2014, and is likely to more than double in the next 20 years. Furthermore, the World Health Organization projected that diabetes will be the seventh leading cause of death in 2030.[8]

Periodontal disease and diabetes mellitus are among the most prevalent chronic diseases worldwide. Their relationship is recognised as bidirectional: diabetes increases the risk and severity of periodontitis, while periodontitis adversely affects glycaemic control and exacerbates diabetic complications.[9] Although numerous studies have investigated this relationship,[10-13] it remains uncertain whether their findings can be directly generalised to other populations.

Thus, the purpose of the present study was to evaluate the cross-sectional correlation between severe periodontitis and diabetes mellitus in a representative sample of the Chinese population based on the data of the 4th National Oral Health Survey in the Mainland of China.

Materials and methods

Ethical approval

The study protocol was approved by the Ethics Committee of the Chinese Stomatological Association (approval no. 2014-003) and the Biomedical Ethics Committee of Peking University School and Hospital of Stomatology (PKUSSIRB-2024102140). Written informed consent was obtained from participants at enrolment.

Study design and sample

Data for the present cross-sectional study were obtained from the 4th National Oral Health Survey in the Mainland of China (2015–2016).[14] Data from adult subjects were included for analysis (Fig 1). Edentulous subjects and subjects without valid information were excluded (Fig 1). The final sample size was 13,195 (4,409, 4,568 and 4,218 for each group, respectively).

Data extraction

Data were extracted from oral examinations and questionnaires.

Periodontal examination data

Periodontal examinations were performed using a community periodontal index probe. A full-mouth examination was carried out. The probe was walked along the gingival crevices with a force of ≤ 20 g to assess bleeding on probing (BOP), presence of calculus, probing depth (PD) and attachment loss (AL). For each parameter, each tooth was scored according to the condition of the most severe site. Calibration training programmes were launched before the survey and the reliability of the results was assessed (kappa values for periodontal pocket depths were higher than 0.6 for involved examiners). In the survey, 5% of the random participants were also selected to test the inter-examiner reproducibility. The kappa values for the three age groups ranged from 0.76 to 0.80.

Periodontal disease was diagnosed according to the new 2018 classification. Thus, periodontally healthy status corresponded to < 10% BOP-positive sites and PD ≤ 3 mm, whereas gingivitis was characterised by > 10% BOP-positive sites and PD ≤ 3 mm. Periodontitis was staged using the algorithm developed by Graetz et al.[15] For each tooth, 1 to 2 mm AL was defined as stage I, 3 to 4 mm as stage II and ≥ 5 mm as stage III. Next, the number of teeth lost was considered (stages I and II, no tooth loss; stage III, four or fewer teeth lost; and stage IV, five or more teeth lost. It should be noted that reasons for tooth loss were not considered here). The complexity of management was also evaluated. Stage II patients were reclassified as stage III if the maximum PD was ≥ 6 mm. Stage III patients were reclassified as stage IV if there were fewer than 10 opposing pairs of teeth).

Interview data from the questionnaire

Data on diabetes were collected using a questionnaire during face-to-face interviews. Information regarding whether subjects had diabetes or not was collected from their self-reported records in the questionnaires.

Data on demographics, socioeconomic status, personal habits, dental history and attitudes towards health were collected using a questionnaire during face-to-face interviews. The following information was extracted for analysis:

- age (years);
- annual family income (with 10,000 yuan as the unit);
- sex (male versus female);
- highest level of education (no schooling, primary school, junior high school, high school, technical specialised school, junior college, undergraduate, master's or higher);
- self-reported diabetes (yes or no);
- smoking status (current smoker, former smoker or non-smoker);
- region (urban versus rural).

Statistical analysis

Data were evaluated using the IBM SPSS Statistics 19 software package (SPSS; Armonk, NY, USA). The primary outcome was periodontal status (health, gingivitis and periodontitis including Stage I, II, III and IV according to the 2018 classification). Stage I and II periodontitis was considered mild-moderate and Stage III and IV periodontitis was considered severe. The secondary outcomes were percentage/numbers of affected teeth with varied periodontal parameters (PD ≥ 4/6 mm, AL ≥ 4/6 mm and missing teeth). Descriptive statistics were computed for all variables. Continuous data were reported as means and standard deviations (SDs), whereas categorical data were summarised as numbers (n) and percentages. For bivariate analyses, comparisons were made between diabetic and non-diabetic subjects, with categorical outcomes compared using a Chi-square test and continuous outcomes (e.g., percentages of teeth with PD ≥ 4 mm) compared using a Mann-Whitney U test. Subgroup analyses were performed by stratifying the population by age group and smoking status, with the same statistical tests (Chi-square or Mann-Whitney U) applied within each stratum to explore potential effect modification. To isolate the independent association between diabetes and periodontal status/parameters, logistic regression models were employed. These models adjusted for potential confounders, including sex, smoking status, region, highest level of education and annual family income. The results were presented as odds ratios (ORs) with their corresponding 95% confidence intervals (CIs). For all statistical tests, a two-sided P value of < 0.05 was considered statistically significant.

Results

Population characteristics

Data from 13,195 dentate subjects (6,575 men and 6,620 women) were analysed. The mean age of the subjects was 56.43 ± 12.40 years. There were 3,472 non-smokers (26.30%), 8,405 current smokers (63.71%) and 1,318 former smokers (9.99%). A total of 1,077 subjects (89 in the 35- to 44-year-old group, 473 in the 55- to 64-year-old group and 515 in the 65- to 74-year-old group) were diabetic.

Higher prevalence of severe periodontitis in diabetic subjects

Distributions of the frequencies of periodontal status by age group and smoking status of diabetic and non-diabetic subjects are shown in Tables 1 and 2.

Generally, the difference in the prevalence of periodontal disease was insignificant between diabetic and non-diabetic subjects (88.39% vs 87.08%, P = 0.215). Subgroup analysis showed that the differences in the prevalence of periodontal disease were all insignificant between diabetic and non-diabetic patients in the 35- to 44-year-old group (88.76% vs 84.07%, P = 0.230), the 55- to 64-year-old group (89.64% vs 89.89%, P = 0.865) and the 65- to 74-year-old group (87.18% vs 87.47%, P = 0.855). Similarly, no significant differences were found between diabetics and non-diabetics in non-smokers

Table 1 Distribution of periodontal status by age groups in diabetic and non-diabetic subjects.

Group	All			35–44 years			55–64 years			65–74 years		
	Non-diabetic subjects (n = 10,041)	Diabetic subjects (n = 3,154)	*P* value	Non-diabetic subjects (n = 4,320)	Diabetic subjects (n = 89)	*P* value	Non-diabetic subjects (n = 3,272)	Diabetic subjects (n = 1,296)	*P* value	Non-diabetic subjects (n = 2,636)	Diabetic subjects (n = 1,582)	*P* value
Periodontal disease (gingivitis and periodontitis)	87.08%	88.39%	0.215	84.07%	88.76%	0.230	89.89%	89.64%	0.865	87.47%	87.18%	0.855
Severe periodontitis (Stage III and IV)	30.22%	41.88%	< 0.001	10.25%	26.96%	< 0.001	37.27%	41.65%	0.063	45.75%	44.66%	0.643

Table 2 Distribution of periodontal status by smoking status in diabetic and non-diabetic subjects.

Group	Non-smokers			Smokers			Former smokers		
	Non-diabetic subjects (n = 7,716)	Diabetic subjects (n = 689)	*P* value	Non-diabetic subjects (n = 3,272)	Diabetic subjects (n = 1,296)	*P* value	Non-diabetic subjects (n = 2,636)	Diabetic subjects (n = 1,582)	*P* value
Periodontal disease (gingivitis and periodontitis)	86.40%	88.24%	0.940	87.88%	87.71%	0.176	89.28%	90.13%	0.748
Severe periodontitis (Stages III and IV)	25.97%	36.57%	< 0.001	36.74%	51.70%	< 0.001	40.39%	50.66%	0.016

(88.24% vs 86.40%, $P = 0.940$), current smokers (87.71% vs 87.88%, $P = 0.176$) and former smokers (90.13% vs. 89.28%, $P = 0.748$).

However, the prevalence of severe periodontitis (Stages III and IV according to the 2018 classification) was significantly higher in diabetics (41.88% vs 30.22%, $P < 0.001$). The differences were more distinct in younger subjects. Subgroup analysis showed that the differences in the prevalence of periodontitis were significant between diabetics and non-diabetics only in the 35- to 44-year-old group (26.96% vs 10.25%, $P < 0.001$) but not in the 55- to 64-year-old group (41.65% vs 37.27%, $P = 0.063$) or 65- to 74-year-old group (44.66% vs 45.75%, $P = 0.643$). The differences in prevalence between diabetics and non-diabetics were all significant in non-smokers (36.57% vs 25.97%, $P < 0.001$), current smokers (51.70% vs 36.74%, $P < 0.001$) and former smokers (50.66% vs 40.39%, $P = 0.016$).

Worse periodontal status in diabetic subjects

Figure 2 presents a comparison of the percentage of affected teeth between diabetic and non-diabetic subjects, using different periodontal parameter cut-offs. Generally, diabetic subjects had significantly higher percentages of teeth meeting each periodontal criterion than non-diabetic subjects (22.88% vs 15.56% for PD ≥ 4 mm, 5.61% vs 1.20% for PD ≥ 6 mm, 25.28% vs 18.30% for AL ≥ 4 mm and 12.91% vs 4.83% for AL ≥ 6 mm, respectively). The pattern of these differences varied across the age subgroups. In the 35- to 44-year-old group, the percentages of teeth with PD ≥ 4 mm, PD ≥ 6 mm, AL ≥ 4 mm and AL ≥ 6 mm were significantly higher in diabetic subjects. In the 55- to 64-year-old group, the percentage of teeth with PD ≥ 4/6 mm was significantly higher in diabetic subjects. In the 65- to 74-year-old group, the percentage of teeth with AL ≥ 4/6 mm was significantly higher in diabetic subjects. Variation was also observed in the subgroup analysis by smoking status (Fig 3). Among current smokers, the percentages of teeth with PD ≥ 4 mm, PD ≥ 6 mm, AL ≥ 4 mm and AL ≥ 6 mm were significantly elevated in diabetic subjects. However, for non-smokers, only the percentage of teeth with PD/AL ≥ 4 mm differed significantly. Similarly, among former smokers, the percentage of teeth with AL ≥ 4 mm was higher in diabetic subjects.

Comparisons of the number of affected teeth between diabetic and non-diabetic subjects, based on different periodontal parameter cut-offs, are presented in Fig 4. Overall, diabetic subjects had a significantly greater number of affected teeth than non-diabetic subjects at specific periodontal thresholds (4.43 vs 3.64 for PD ≥ 4 mm, 0.35 vs 0.25 for PD ≥ 6 mm, 5.19 vs 3.97 for AL ≥ 4 mm and 1.21 vs 0.87 for AL ≥ 6 mm, respective-

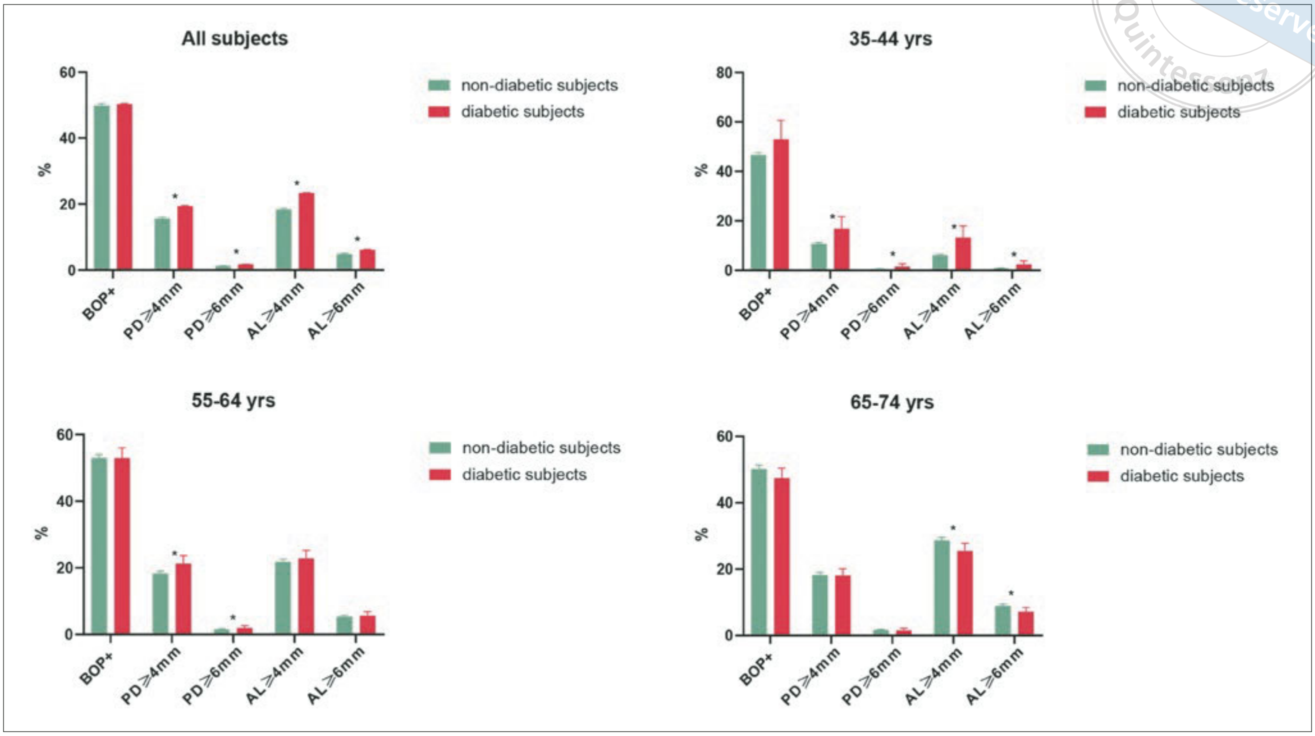

Fig 2 Comparison of percentage of teeth affected by age groups between diabetic and non-diabetic subjects. *Significant difference according to Student *t* test. %, percentage of periodontal parameter.

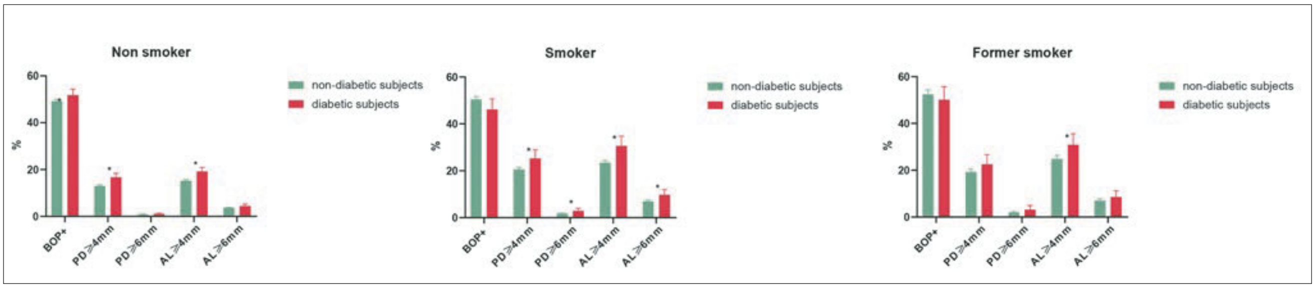

Fig 3 Comparison of percentage of teeth affected by smoking status between diabetic and non-diabetic subjects. *Significant difference according to Student *t* test.

ly). Interestingly, the pattern of these differences varied across age subgroups. In the 35- to 44-year-old group, all parameters differed significantly between diabetic and non-diabetic subjects. In the 55- to 64-year-old group, only the number of teeth with PD ≥ 4 mm showed a significant difference. No parameters were significantly different in the 65- to 74-year-old group. The patterns also varied based on smoking status (Fig 5). Among current smokers, all parameters except for PD ≥ 4 mm differed significantly. Among non-smokers, all parameters except for BOP+, PD ≥ 6 mm differed significantly. Among former smokers, only the number of teeth with AL ≥ 4 mm and AL ≥ 6 mm differed significantly. A significantly larger number of missing teeth was found in diabetic subjects (Fig 6). Similar trends for missing teeth were observed in the 35- to 44-year-old group, current smokers and non-smokers.

Increased risk of diabetes in subjects with severe periodontitis

The risk of diabetes of patients with different periodontal status is shown in Fig 7. Overall, compared to periodontally healthy subjects, a significantly higher risk of diabetes was observed in those with Stage III periodontitis (OR 1.363), and a significantly higher risk of

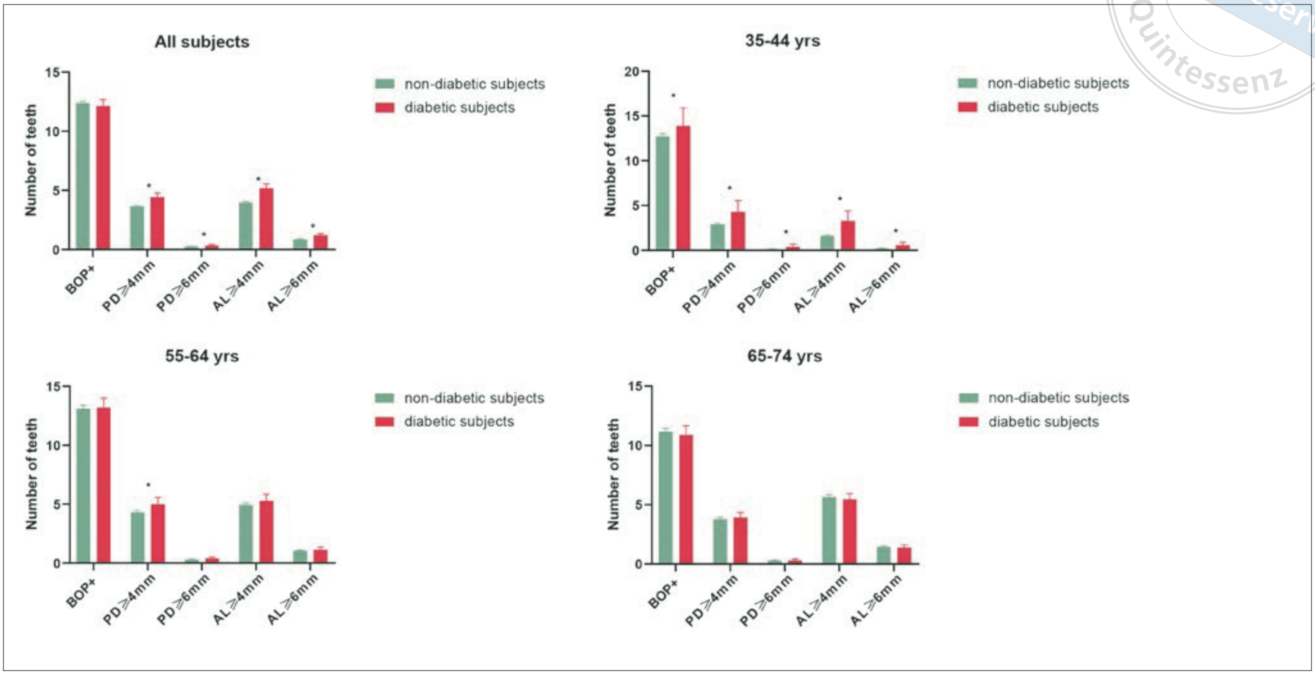

Fig 4 Number of teeth affected by age groups between diabetic and non-diabetic subjects. *Significant difference according to Student *t* test.

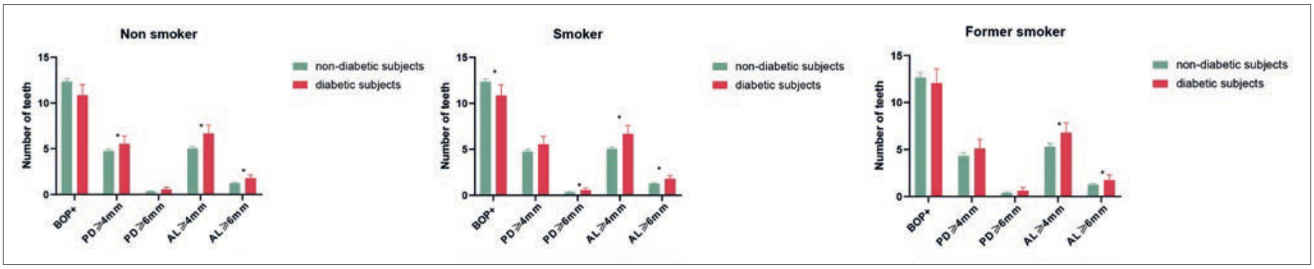

Fig 5 Number of teeth affected by smoking status between diabetic and non-diabetic subjects. *Significant difference according to Student *t* test.

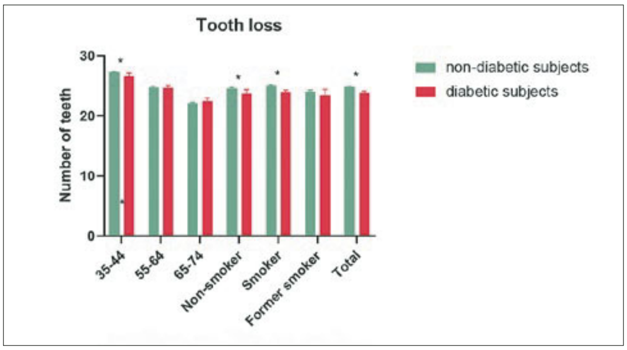

Fig 6 Number of missing teeth by age groups and smoking status between diabetic and non-diabetic subjects. *Significant difference according to Student *t* test

diabetes was observed in those with severe periodontitis (OR 1.512). In the 35- to 44-year-old group, a significantly higher risk of diabetes was observed in those with Stage III (OR 2.277) and IV periodontitis (OR 8.900), and a significantly higher risk of diabetes was observed in those with severe periodontitis (OR 3.104). However, no significant correlations were found between other periodontal statuses (e.g., periodontally healthy, Stage I or II periodontitis) and diabetes risk.

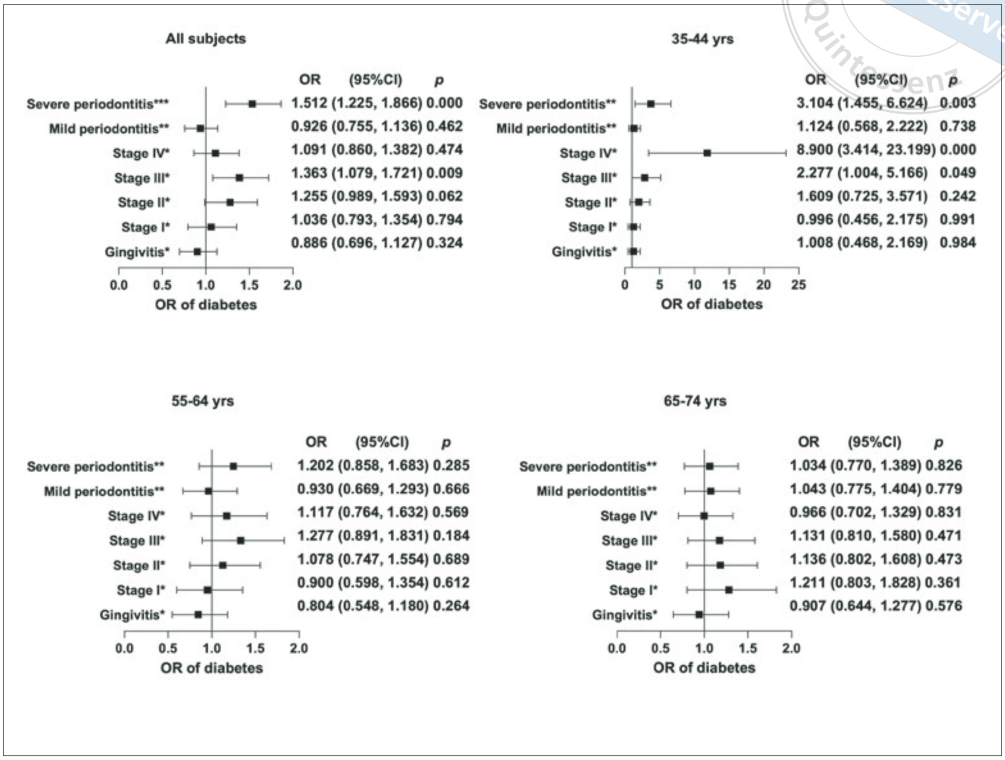

Fig 7 Forest plots of ORs of diabetes of subjects with different periodontal status by age group, according to the 2018 classification.

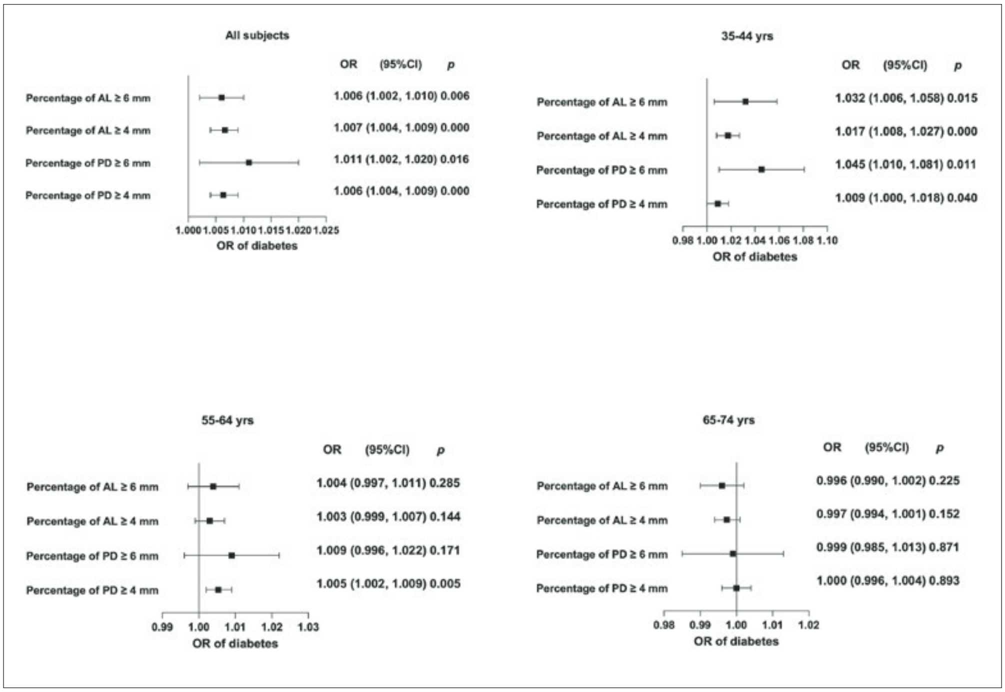

Fig 8 Forest plots of ORs of diabetes of percentages of teeth affected with different cut-offs.

Positive associations between diabetes and periodontal parameters

Figures 8 and 9 illustrate the correlation between diabetes and the percentages/numbers of teeth affected by various periodontal cut-offs. A significantly positive correlation was demonstrated between diabetes and the percentages of teeth with PD ≥ 4 mm, PD ≥ 6 mm, AL ≥ 4 mm and AL ≥ 6 mm in all subjects (Fig 8) and in the 35- to 44-year-old group. However, this correlation was

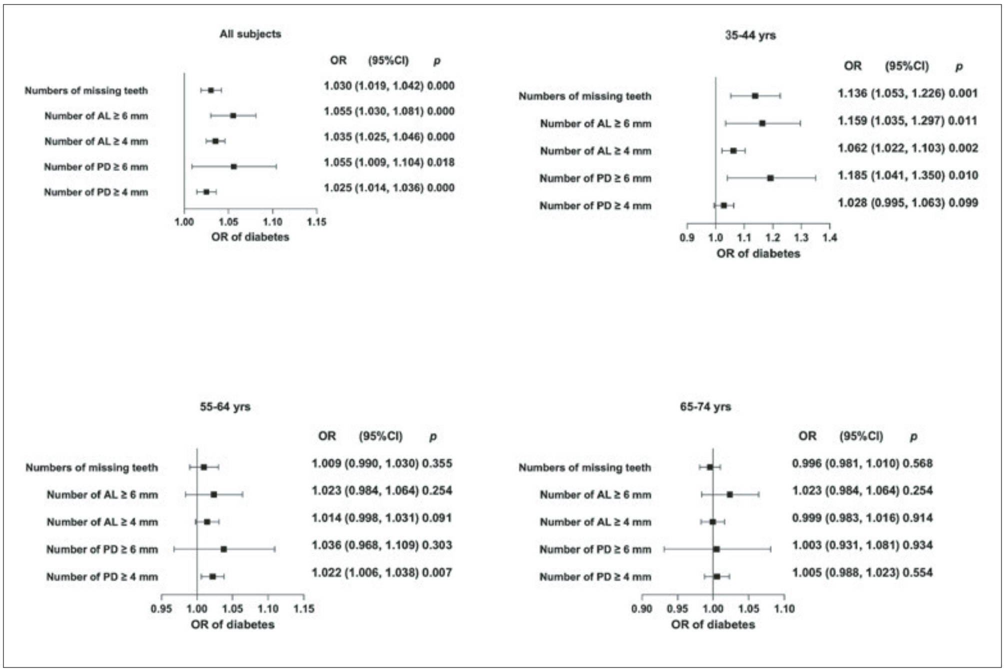

Fig 9 Forest plots of ORs of diabetes of numbers of teeth affected with different cut-offs.

not observed in the 55- to 64-year-old or 65- to 74-year-old groups. Similar trends were found for the relationships between diabetes and the number of teeth with PD ≥ 6 mm, AL ≥ 4 mm and AL ≥ 6 mm in all subjects and in the 35- to 44-year-old group (Fig 9).

Discussion

This nationwide cohort study, utilising a representative sample of the Chinese population, established a significant link between severe periodontitis and diabetes, particularly among younger subjects.

The study, based on a nationwide oral health survey conducted in in China, confirms a significant cross-sectional link between severe periodontitis and diabetes, evidenced by an increased OR. This finding aligns with the global body of evidence. A report from the Workshop of the International Diabetes Federation (IDF) and the European Federation of Periodontology (EFP) summarised that periodontitis is correlated with a higher risk of incident diabetes, with a hazard ratio ranging from 1.2 to 1.3.[16] Supporting this, the Spanish nationwide cohort study (di@bet.es study) also demonstrated a cross-sectional link, where participants with severe periodontitis had a markedly elevated unadjusted risk of developing diabetes (range 3.0 to 6.1) and prediabetes (range 2.2 to 2.8) over an 8-year period.[17] This link persisted for extensive attachment loss even in fully adjusted models.[17] The present results in the Chinese population reinforce these conclusions. The authors not only found severe periodontitis to be significantly linked with diabetes but also identified a positive link between the presence of teeth with deep PD (≥ 4/6 mm) and AL (≥ 4/6 mm) and diabetes, specifically within the younger 35- to 44-year-old group.

Corroborating previous findings, the present study demonstrates a significantly elevated burden of diabetes in periodontitis subjects. A cross-sectional study (2009 to 2012) conducted in the US of over 10,000 individuals, representing 143 million dentate adults, established that adults aged ≥ 30 years with diabetes suffer from more moderate or severe periodontitis compared to those with normal glucose levels.[18] The present study confirms this pattern, revealing a significantly higher prevalence of severe periodontitis in diabetic subjects. Specifically, the percentage and number of teeth with PD ≥ 4 mm, PD ≥ 6 mm, AL ≥ 4 mm and AL ≥ 6 mm were significantly greater in diabetic than non-diabetic subjects. PD is a good indicator of the present inflammatory condition of the periodontium and a widely used method in research and clinical work to assess periodontal health. The adjusted rate ratios for incident diabetes among subjects with PD 4 to 5 mm and among subjects with PD ≥ 6 mm were 1.32 and 1.56, respectively, compared to dentate subjects without deepened periodontal pockets (PD ≥ 4 mm).[19] The present results were consistent with several cohort studies. For patients with severe periodontitis, the incidence of diabetes was significantly higher compared to those with mild periodontitis.[19,20]

Poor glycaemic control in diabetes is associated with poorer periodontal status and outcomes. Periodontitis is connected with dysglycaemia and increased insulin resistance in people with diabetes, as well as increased risk of incident diabetes and diabetic complications. Periodontitis is understood to negatively impact diabetes through several mechanisms, including bacteraemia, vascular inflammation and systemic oxidative stress, which impair beta cell function.[21] The effect of periodontitis on diabetes control may originate from seepage of periodontal inflammation mediators into the serum and cause a systemic inflammatory state. Potential key factors that are considered mediators between periodontal inflammation and glucose homeostasis include IL-6, TNF-α and CRP as well as oxygen radicals. All these mediators are implicated with impaired insulin signalling and resistance.[22] Some studies also suggest that increased systemic oxidative stress due to periodontal infection may activate systemic pro-inflammatory pathways that could influence diabetes.[22,23] There is an urgent need to raise awareness among healthcare professionals, patients and health authorities about the importance of periodontal health in diabetes management. Reflecting this, NHS England published a commissioning standard for dental care in people with diabetes in 2019.[24] Furthermore, the National Institute of Health and Care Excellence incorporated periodontal treatment as a key intervention within its diabetes care guidelines.[25,26]

A significantly positive link was observed between diabetes and the percentages of teeth with PD and AL ≥ 4/6 mm in the 35- to 44-year-old group but not in the older cohorts (55- to 64-year-old and 65- to 74 year-old groups). This indicates that severe periodontitis is linked with diabetes particularly in young adults. Consequently, there is a need to enhance education and awareness of dental treatment and preventive management for individuals at risk of diabetes, with a focus on younger populations. The chronic nature of both periodontitis and diabetes implies that it takes time for the risk factors to contribute to the development of these two chronic diseases. Since younger individuals have had less cumulative exposure to these risk factors, the impact of severe periodontitis as a contributing factor may be more discernible. Therefore, severe periodontitis may play a more significant role in the development of diabetes in younger subjects, potentially due to its pronounced inflammatory burden.

One limitation of this study is the reliance on self-reported diabetes diagnoses. Although the use of self-reported data introduces the potential for recall and reporting bias, the present authors sought to mitigate this through face-to-face interviews and by confirming that the diagnosis was provided by a hospital. Nevertheless, this method may be less accurate than objective clinical measurements, such as fasting plasma glucose or HbA1c, which are considered the gold standard. However, for large-scale epidemiological studies this one (n = 13,195), self-reported diagnosis remains a practical and cost-effective approach, as evidenced by its use in prior research on this topic. A further limitation is the cross-sectional nature of the present data, which precludes the determination of temporal sequence. Therefore, although the present authors demonstrate a significant link between severe periodontitis and diabetes, they cannot confirm whether periodontitis developed before or after the onset of diabetes. Consequently, the findings indicate a relationship but do not imply causality.

Conclusion

In summary, this large-scale study identifies severe periodontitis as a significant indicator correlated with an elevated risk of diabetes, a correlation that was particularly pronounced in younger adults. This established link between two highly prevalent diseases warrants heightened awareness among clinicians about the importance of periodontal health and periodontal treatment in diabetes management.

Conflicts of interest

The authors declare no conflicts of interest related to this study.

Author contribution

Dr Jian JIAO participated in the data analysis and collation; Dr Ya Lin ZHAN contributed to the manuscript writing and data analysis and collation; Dr Wu Di JING participated in writing the manuscript; Drs Xi Ping FENG, Bao Jun TAI, De Yu HU, Huan Cai LIN, Bo WANG, Chun Xiao WANG, Shu Guo ZHENG, Xue Nan LIU, Wen Sheng RONG, Wei Jian WANG, Xing WANG and Yan SI conceived the study design and drafted the protocol; Dr Huan Xin MENG conceived the study design, drafted the protocol and revised the manuscript. The manuscript has been read and approved by all the authors.

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