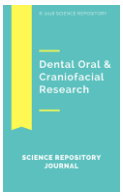


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**Research Article**

# High Waist Circumference Obesity has a Greater Association with Periodontitis among a Chinese Population

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ABSTRACT

Recent studies have reported a relationship between obesity and periodontitis, but few have investigated this association in China. This present study probes the relationship between obesity and periodontitis within a population of China. A total of 582 Chinese subjects were analyzed with fifty-three excluded. All participants underwent a periodontal assessment, anthropometric measurements and completed a questionnaire. Periodontal status was evaluated with the Community Periodontal Index. Body mass index (BMI) and waist circumference (WC) were used as measures of overall body fat and upper body fat, respectively. Data from young and elderly subjects were analyzed separately. Though there was no association between BMI and periodontitis, the risk for periodontitis was increased by 5.1% per 1-cm increase in WC (OR=1.051, 95%CI: 1.025-1.079, P<0.05). Within this population in China, abdominal obesity was significantly associated with an increased prevalence, severity, and extent of periodontitis, suggesting that individuals with high WC circumference obesity should pay more attention to their periodontal health.



## Introduction

Obesity is one of the most blatantly visible, yet most neglected, public health problems threatening human health. It is defined as the deposition of abnormal or excessive fat in the adipose tissue [1]. According to a recent statement from the World Health Organization (WHO), obesity is rising in developing countries due to a global shift in life-style-related factors, including accumulating energy, fat and sugar consumption and less physical activity [2-6]. The changes in modern life-styles, including a diet with an increased intake of fats, and sugars, and decreased physical activity, contribute to this global phenomenon.

Obesity is expected to be the leading threat to human health in the 21st century. As determined by body mass index, waist-to-hip circumference ratio, percentage of body fat, or maximum oxygen consumption, obesity is a verified risk factor for chronic conditions, including type 2 diabetes, hyperlipidemia, cardiovascular disease, hypertension, and cholelithiasis,

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and has been proposed to be a factor for susceptibility of periodontitis [2, 3, 5, 7-14].

Despite that most epidemiological studies have shown an association between obesity and periodontitis and that obesity significantly contributes to the severity of periodontitis in experimental animals, study results have been inconsistent with regard to age, gender, degree of correlation, and the causal relationship between obesity and periodontitis, and the potential underlying biological mechanism remains to be established [15, 16]. Furthermore, body mass index (BMI) was adopted by a majority of studies as an indicator of obesity, while only a limited number of studies used the combined indicators of overweight and obesity. However, as BMI does not account for body frame size and weight types, the accuracy of BMI for setting obesity standards is still controversial. Thus, the measurement of waist circumference (WC) has been proposed as a better disease risk predictor in recent studies, and WC could better reflect abdominal obesity.

In this study, we aimed to determine whether being overweight or obese is associated with an increased risk of having periodontitis after adjusting for factors such as age, gender, and smoking status among a sample population in China and to determine whether the association is consistent in young and middle-aged, and older subjects.

## Material and Methods

### Study Sample and Participants

A systematic random sample of 582 persons aged between 20 and 85 years was chosen from subjects who attended an annual examination at Tianjin Medical University Medical Center in China. All protocols were approved by the Research Ethical Committee of Tianjin Medical University, China. The methods were carried out in accordance with the approved guidelines. Informed consent was obtained from all participants. The exclusion criteria for all subjects included the following: periodontal or antibiotic therapy in the previous 6 months; any condition that might influence the outcome of a periodontal examination; or any questionnaire or medical report that was incomplete. Fifty-three persons were excluded for the following reasons: incomplete questionnaire (n=7), received periodontal treatment in the past 6 months (n=22), total edentulism (n=9), cardiovascular disease (n=8), and having fewer than 6 teeth (n=7). The consultation rate was 90.89%. This screen of 529 people included 287 men and 242 women (Fig. 1). The data for this research were collected by interviews and clinical oral and health examinations.

### Questionnaire

A trained interviewer administered and completed the questionnaire for each subject. Age, gender, nationality, marital status, and education level were included in socio-demographic characteristics. A family history of diabetes, hypertension, dyslipidemia, osteoporosis, and periodontitis was also collected.

In addition, the frequency of tooth brushing (categorized as twice a day or more, daily, or less often), history of dental checkups (categorized into those who have dental check-ups regularly, not regularly, only when symptoms occur, or never), stress (whether it could be dealt easily or barely), smoking (defined as current smoker, past smoker, or non-smoker), alcohol consumption (defined as drinker or non-drinker), and other risk indicators of periodontitis were assessed.

### Assessment of obesity

A professional nutritionist measured the subjects' weight, height, and WC while the subject was dressed in light clothing and not wearing shoes. A measuring rod and a mechanical flat scale were used to measure height and body weight, respectively. WC was measured to the nearest centimeter at the narrowest point between the umbilical and the rib cage with a circumference-measuring tape.

BMI was calculated as the ratio of the weight (kg) to the square of the height (m). According to the Health Ministry Disease Control Department guidelines, obesity for men and women was defined as BMI≥28 kg/m², overweight as BMI ≥24 kg/m² to <28 kg/m², normal weight as BMI ≥18.5 kg/m² to <24 kg/m², and underweight as BMI<18.5 kg/m². According to the International Diabetes Federation, abdominal obesity based on WC was defined as a WC ≥90 cm for men and ≥80 cm for women.

### Oral Examinations

All participants underwent a clinical oral examination performed by a dentist. The percent agreement between the examiner and the reference examiner with respect to periodontal pockets was 72%. To assess the periodontal condition, the WHO community periodontal index was used. The 10 teeth selected for measurements were as follows: the maxillary right central incisor, the maxillary right first molar, the maxillary right second molar, the maxillary left first molar, the maxillary left second molar, the mandibular left central incisor, the mandibular left first molar, the mandibular left second molar, the mandibular right first molar, and the mandibular right second molar. The 10 selected teeth were assessed using the plaque index (PLI) of Silness and Loe(1964), the calculus index (CI) of Green and Vermillion(1964), and the sulcus bleeding index (SBI) of Mazza (1981) [17]. Six sites (mesio-facial, mid-facial, disto-facial, mesio-lingual, mid-lingual, and disto-lingual) of each studied tooth were assessed and scored for the probing depth (PD) and the attachment loss (AL). The number of missing teeth (excluding third molars) per subject was recorded. The mean PLI, CI, SBI, PD, and AL over all examined surfaces or sites and the percentages of sites with PD≥4 mm, PD≥6 mm, AL≥1 mm, Al≥3 mm, and Al≥5 mm was calculated for each participant. The extent and severity of periodontitis were defined by the percentage of periodontal sites.

### Statistical Analysis

The Statistical Package for Social Sciences (SPSS 16.0) software was used for data processing and data analysis. The characteristics of the subjects' variables were described using frequency distribution for categorical variables and the mean and standard deviation for continuous variables. One-way analysis of variance ($\chi^2$ test for categorical variables and T test for continuous variables) was used to determine whether there were any significant differences ($P$<0.05) between groups. The selection of covariates was based on the current knowledge of the potential risk factors of periodontal infection. The prevalence of periodontitis served as the dependent variable, and all of the risk factors were added as the

independent variables in the multivariate logistic regression analysis. This procedure provided regression analysis and analysis of variance for the dependent variable (prevalence of periodontitis) by explanatory variables and covariates, including one obesity indicator every time. The association between each risk factor and the prevalence of periodontitis was determined by the use of multivariate binary logistic regression after adjusting for important variables. Then the best regression model was constituted by all variables that were significantly associated with periodontitis. To verify the associations between BMI, WC, and other risk factors and periodontitis, obesity indicators were tested by adding them to the best models in separate models. Forward stepwise regression was conducted to assess the statistical significance of the two-way interactions between independent variables.

The two-way interaction terms were added one at a time to the model containing all of the main effects and were assessed for their significance using the likelihood ratio test. Crude and adjusted odds ratios (OR) and their 95% confidence intervals were calculated. A *p*-value of<0.05 was considered statistically significant. We then analyzed groups by age as young or middle-aged (20–59 years) or older-aged (60 years and older) in addition to the overall group to explore whether the associations were consistent in younger and older adult subjects. The analysis of the association between obesity indicators and periodontal parameters (PD mean, AL mean, percentage of surfaces with PD≥4 mm, PD≥6 mm, AL≥1 mm, Al≥3 mm, and Al≥5 mm) was conducted using the Wilcoxon rank sum test to explore whether obesity would affect the severity of periodontitis.

**Figure**

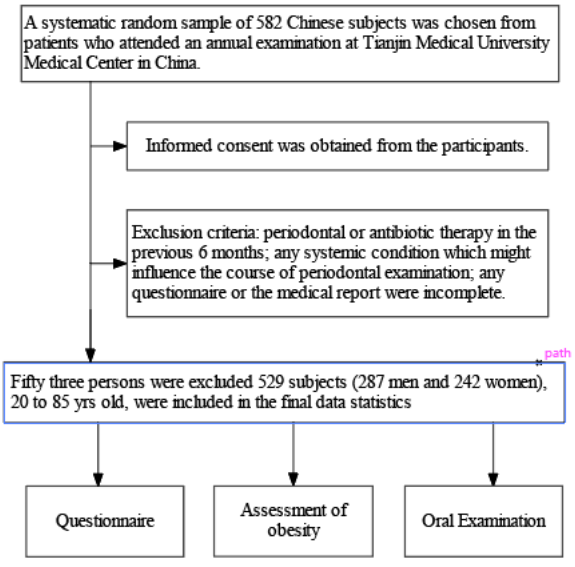


**Fig 1:** Study design from screening to completion of the trial.

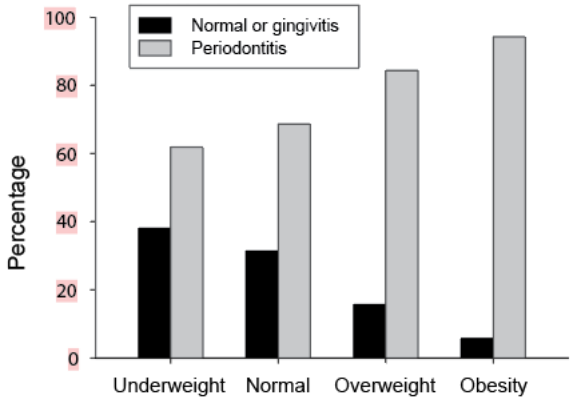


**Fig 2:** The prevalence of periodontitis according to body mass index (BMI) categories. Approximately 68.61% of normal weight participants had periodontitis, whereas 84.34% of overweight and 94.25% of obese participants had periodontitis.

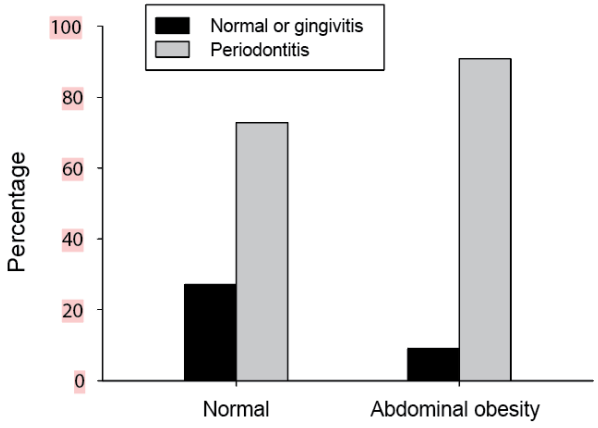


**Fig 3:** The prevalence of periodontitis according to waist circumference (WC). According to WC, 72.80% of normal WC participants had periodontitis, whereas 90.91% of participants with abdominal obesity had periodontitis

**Results**

This study included a total of 529 participants (287 males and 242 females) aged between 21 and 85 years (mean age ± standard deviation [SD] of 41.0± 13.5 years). The basic characteristics of the study population and the prevalence of periodontitis according to socio-demographic, oral health parameters, and clinical and relevant characteristics are shown in Table 1. According to BMI, 37.4% were overweight, and 16.4% were obese. Approximately 31.2% had abdominal obesity according to WC. Of the 529 subjects who were examined, 78.4% had periodontitis. The prevalence of periodontal disease increased with advancing age, and all of the subjects had in the 70-year-old age subgroup had peridontitis. The prevalence of periodontitis according to BMI categories and WC are shown in Fig. 2 and Fig. 3, respectively. Approximately 68.61% of normal weight participants had periodontitis, whereas 84.34% of overweight and 94.25% of obese participants had periodontitis. Of participants with normal WC, 72.8% had periodontitis, whereas 90.91% of participants with abdominal obesity had periodontitis.

According to the research variables and confounding variables, most of the studied independent variables in the univariate analysis ($\chi^2$ test for categorical variables and T test for continuous variables) were significantly associated with the odds of having periodontitis ($P$<0.05); these included age ($\chi^2$=89.047, $P$<0.001), gender ($\chi^2$=32.476, $P$<0.001), education ($\chi^2$=14.259, $P$<0.001), BMI ($\chi^2$=32.581, $P$<0.001), abdominal obesity ($\chi^2$=29.864, $P$<0.001), smoking ($\chi^2$=27.472, $P$<0.001), drinking ($\chi^2$=11.158, $P$=0.001), hypertension ($\chi^2$=17.700, $P$ <0.001), hyperlipidemia ($\chi^2$=21.499, $P$ <0.001), high triglycerides ($\chi^2$=26.992, $P$ <0.001), high cholesterol ($\chi^2$=6.586, $P$ =0.01), and WC (t = − 8.621, $P$ <0.001).

Although most of the studied variables were significantly associated with the increased odds of having periodontitis, we could not rule out the interference of confounding factors after adjusting for important variables in the univariate analysis, including gender, nationality, education, dental attendance pattern, tooth brushing frequency and time, alcohol consumption, stress, family history of periodontitis, diabetes mellitus, hypertension, hyperlipidemia, elevated cholesterol level, and elevated triglyceride level. Only age (OR=1.949, 95%CI: 1.531, 2.481), high WC (OR=1.051, 95%CI: 1.025, 1.079), and smoking (OR=2.246, 95%CI: 1.309, 3.914) remained significantly associated with the increased odds of periodontitis in the entire group (Supplementary Table 1). Each 1-cm increase in WC was associated with a 5.1% increase in the risk of periodontitis.

Logistic regression was performed again after grouping, and Supplementary (table 2) shows that in the young and middle-aged groups (20–59 years), overweight and obesity defined by BMI was associated with an increased risk of periodontitis (OR=1.511, 95% CI: 1.023, 2.353, $P$<0.05) in addition to age (OR=2.290, 95%CI: 1.654, 3.169), gender (OR=0.453, 95%CI: 0.260, 0.789), and smoking (OR=2.053, 95%CI: 1.167, 3.612). However, there was no consistent association between obesity and periodontitis among the older-aged group (Supplementary Table 3) after adjusting for important variables.

Table 2 shows the periodontal parameters according to BMI. Compared with subjects who had normal weight or who were underweight (BMI<24 kg/m$^2$), overweight and obese subjects had a significantly higher average of PD, AL, percentage of sites with PD ≥4 mm, PD ≥6 mm, Al ≥1 mm, and Al ≥3 mm ($P$<0.05). Obese subjects had a significantly higher percentage of sites with PD ≥4 mm and Al ≥3 mm compared with overweight ($P$<0.05). Table 3 shows that all of the periodontal parameters including average PD, AL, and the percentage of sites with PD ≥4 mm, PD ≥6 mm, Al ≥1 mm, Al ≥3 mm, and Al ≥5 mm were significantly higher among subjects with abdominal obesity ($P$<0.05).

**Table 1:** The basic characteristics of the study population and the prevalence of periodontitis according to socio-demographic, oral health parameters, and clinical and relevant characteristics

| Variable | Total (%) | Periodontal status | | *p*-value |
|---|---|---|---|---|
| | | Normal or gingivitis n (%) | Periodontitis n (%) | |
| Age (years) | | | | <0.001 |
| 20~29 | 133(25.1) | 66(49.62) | 67(50.38) | |
| 30~39 | 139(26.3) | 22(15.83) | 117(84.17) | |
| 40~49 | 122(23.1) | 19(15.57) | 103(84.43) | |
| 50~59 | 80(15.1) | 5(6.25) | 75(93.75) | |
| 60~69 | 35(6.6) | 2(5.71) | 33(94.29) | |
| 70+ | 20(3.8) | 0(0) | 20(100) | |
| Gender | | | | <0.001 |
| Male | 287(54.3) | 35(12.20) | 252(87.80) | |
| Female | 242(45.7) | 79(32.64) | 163(67.36) | |
| Nationality | | | | 1.000 |
| Han | 510(96.4) | 110(21.57) | 400(78.43) | |
| Others | 19(3.6) | 4(21.05) | 15(78.95) | |
| Education | | | | <0.001 |
| High school and above | 77(14.6) | 4(5.19) | 73(94.81) | |
| University degree or above | 452(85.4) | 110(24.34) | 342(75.66) | |
| Dental attendance pattern | | | | 0.149 |
| Regularly | 5(0.9) | 2(40) | 3(60) | |
| Not regularly | 98(18.5) | 27(27.55) | 71(72.45) | |
| When have symptoms | 275(52.0) | 60(21.82) | 215(78.18) | |
| Never | 151(28.5) | 25(16.56) | 126(83.44) | |
| Brushing frequency | | | | 0.127 |
| Once a day or none | 117(22.1) | 19(16.24) | 98(83.76) | |
| At least twice a day | 412(77.9) | 95(23.06) | 317(76.94) | |
| Brushing time | | | | 0.194 |
| Less than 3 minutes | 465(87.9) | 96(20.65) | 369(79.35) | |
| At least 3 minutes | 64(12.1) | 18(28.13) | 46(71.87) | |
| Body Mass Index (BMI)⁎ | | | | <0.001 |
| Underweight | 21(4.0) | 8(38.10) | 13(61.90) | |
| Normal | 223(42.2) | 70(31.39) | 153(68.61) | |
| Overweight | 198(37.4) | 31(15.66) | 167(84.34) | |
| Obesity | 87(16.4) | 5(5.75) | 82(94.25) | |

| Variable | Total (%) | Periodontal status | | *p*-value |
|---|---|---|---|---|
| | | Normal or gingivitis n (%) | Periodontitis n (%) | |
| Waist circumference † | | | | <0.001 |
| Normal | 364(68.8) | 99(27.20) | 265(72.80) | |
| Abdominal obesity | 165(31.2) | 15(9.09) | 150(90.91) | |
| Smoking | | | | <0.001 |
| No | 404(76.4) | 108(26.73) | 296(73.26) | |
| Past | 38(7.2) | 3(7.90) | 35(92.10) | |
| Current | 87(16.7) | 3(3.45) | 84(96.55) | |
| Drinking | | | | 0.001 |
| No | 343(64.8) | 89(25.95) | 254(74.05) | |
| Yes | 186(35.2) | 25(13.44) | 161(86.56) | |
| Stress | | | | 0.644 |
| No or less | 372(70.3) | 78(20.97) | 294(79.03) | |
| Large | 157(29.7) | 36(22.93) | 121(77.07) | |
| Diabetes mellitus ‡ | | | | 0.130 |
| No | 505(95.5) | 112(22.18) | 393(77.82) | |
| Yes | 24(4.5) | 2(8.33) | 22(91.67) | |
| Hypertension § | | | | <0.001 |
| No | 442(83.6) | 110(24.89) | 332(75.11) | |
| Yes | 87(16.4) | 4(4.60) | 83(95.40) | |
| Hyperlipidemia ‖ | | | | <0.001 |
| No | 308(58.2) | 88(28.57) | 220(71.43) | |
| Yes | 221(41.8) | 26(11.76) | 195(88.24) | |
| Elevated cholesterol level ¶ | | | | 0.01 |
| No | 381(72.0) | 93(24.41) | 288(72.96) | |
| Yes | 148(28.0) | 21(14.19) | 127(85.81) | |
| Elevated triglyceride level # | | | | <0.001 |
| No | 392(74.1) | 106(27.04) | 286(72.96) | |
| Yes | 137(25.9) | 8(5.84) | 129(94.16) | |

* Underweight (BMI<18.5 kg/m²), normal weight (18.5≤BMI<24 kg/m²), overweight (24≤BMI<28 kg/m²), and obesity (BMI≥28 kg/m²).

† Abdominal obesity: ≥90 cm in males and ≥80 cm in females.

‡ Diabetes mellitus: had history of diabetes, blood sugar≥11.1 mmol/L and/or fasting plasma glucose (FPG)≥7.0 mmol/L.

§ Hypertension: had history of hypertension, or systolic and/or diastolic blood pressure≥140 mmHg.

‖ Hyperlipidemia: total cholesterol≥5.72 mmol/L or triglycerides≥1.70 mmol/L or both.

¶ Elevated cholesterol level: total cholesterol≥5.72 mmol/L.

# Elevated triglyceride level: triglycerides≥1.70 mmol/L.

**Table 2:** Periodontal status according to body mass index (BMI) categories

| | Normal or underweight BMI<24 kg/m² (M±Q) | Overweight 24≤BMI<28 kg/m² (M±Q) | Obesity BMI≥28 kg/m² (M±Q) | *p*-value |
|---|---|---|---|---|
| Mean PD | 2.00±0.36 | 2.28±0.53 * | 2.48±0.34 * | 0.000 |
| Mean AL | 0.39±0.78 | 0.80±0.90 * | 1.00±0.80 * | 0.000 |
| Percentage of sites with | | | | |
| PD≥4 mm | 0.00±5.00 | 5.00±15.42 * | 10.00±15.00 * † | 0.000 |
| PD≥6 mm | 0.00±0.00 | 0.00±0.00 * | 0.00±0.00 * | 0.001 |
| AL≥1 mm | 30.00±59.28 | 55.00±47.78 * | 65.00±40.00 * | 0.000 |
| AL≥3 mm | 0.00±11.11 | 5.00±11.11 * | 5.56±9.29 * † | 0.000 |
| AL≥5 mm | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.222 |

The general distribution of the periodontal indices was not a normal distribution, so the Wilcoxon rank sum test was used in the analysis.
M±Q: median±quartile interval
* Significantly different from normal and underweight.
† Significantly different from overweight.

**Table 3:** Periodontal status according to waist circumference (WC)*

| | Normal (M±Q) | Abdominal obesity (M±Q) | *p*-value |
|---|---|---|---|
| Mean PD | 2.00±0.36 | 2.28±0.53 | 0.000 |
| Mean AL | 0.39±0.78 | 0.80±0.90 | 0.000 |
| Percentage of sites with | | | |
| PD≥4 mm | 0.00±5.00 | 10.00±14.38 | 0.000 |
| PD≥6 mm | 0.00±0.00 | 0.00±0.00 | 0.000 |
| AL≥1 mm | 30.00±60.00 | 65.00±43.33 | 0.000 |
| AL≥3 mm | 0.00±5.00 | 5.56±10.00 | 0.000 |
| AL≥5 mm | 0.00±0.00 | 0.00±0.00 | 0.001 |

*Abdominal obesity: WC≥90 cm for men and ≥80 cm for women.
M±Q: median±quartile interval

**Discussion**

In 1977, Perlstein et al. showed that obese-hypertensive rats are more likely to have periodontal tissue deterioration than normal weight rats [15]. In humans, the first epidemiological survey was conducted in 1998 by Saito in Japan, who reported that obese Japanese subjects were more likely to have periodontal disease than normal weight ones [18]. The association between each risk factor and the prevalence of periodontitis was determined by the use of multivariate binary logistic regression after adjusting for important variables, then the best regression model was constituted by all variables that were significantly associated with periodontitis. To verify the associations between BMI, WC, and other risk factors and periodontitis, obesity indicators were tested by adding them to the best models in separate models. Forward stepwise regression was conducted to assess the statistical significance of the two-way interactions between independent variables.

Additionally, the tracking survey by Saito reported that the relationship between upper body obesity and periodontitis was more significant and that a significant relationship between BMI and periodontal disease was present only in subjects with a high waist-to-hip ratio [19]. Three healthy behaviors, e.g. staying a normal weight, exercising, and eating a healthy diet, have been reported to contribute to a lower prevalence of periodontitis [20]. Shimazaki et al. also found that subjects with the combined lowest quintile in BMI and highest quintile in maximal oxygen consumption ($VO_{2max}$) had a significantly lower risk of severe periodontitis [21].

In our study in Chinese population, an association between WC and periodontitis in the overall group (OR=1.051, 95%CI: 1.025, 1.079) was detected. Each 1-cm increase in WC was associated with a 5.1% increase in the risk of periodontitis after adjusting for confounding factors. There was no association between BMI-defined obesity and periodontitis after adjusting for important variables in the group aged 20–85 years. This observation suggested that in China, abdominal obesity is more significantly associated with periodontitis than peripheral obesity. This finding is consistent with the study conducted by Reeves, who reported that each 1-cm increase in WC was associated with a 5% increase in the risk of periodontitis [22]. Al-Zahrani et al. also found that upper body obesity had a significant relationship with periodontal disease in 643 Japanese subjects, and that WC was significantly associated with the prevalence of periodontal disease (adjusted OR=2.27) [23].

WC is an important indicator of visceral abdominal fat and can reflect abdominal obesity better than BMI. To the best of our knowledge, the types of obesity are considered to be different between Westerners and Orientals. Orientals are more inclined to have upper body obesity, i.e., abdominal adiposity, whereas Westerners are more likely to have whole body obesity. In comparison with peripheral fat, abdominal fat has been suggested to be a higher risk factor; however, visceral fat has the closest relationship with an increased risk [1, 24]. This correlation may explain why WC was more significantly associated with periodontitis than BMI in a Chinese population. In South Korea, Kim et al. also reported that a high WC seemed to be associated with periodontitis, whereas BMI was not, i.e., abdominal obesity was significantly correlated with periodontitis [25].

The results of these studies have been inconsistent regarding age and gender. For example, Saito et al. Genco et al., and Nishida et al. reported an overall association, whereas Al-Zahrani et al [10, 14, 18, 23]. found an association among young subjects. The potential relationship between a high BMI and periodontitis was suggested when Linden et al. investigated a group of subjects aged 60-70 years [12]. In our study and after grouping, BMI-defined overweight and obesity increased the odds of periodontitis (OR=1.511, 95%CI: 1.023, 2.353, p<0.05). In addition, age, gender, and smoking were also associated with an increased risk of periodontitis in the young and middle-aged group (20–59 years). However, in the older aged group (60–85 years), there was no consistent association between obesity and periodontitis, and only a high triglyceride level was a risk factor (OR=1.447, 95%CI: 1.032, 2.257) for periodontitis after adjusting for important variables. The correlation between periodontitis and obesity was significant in the overall group; however, no significant association was found when the middle- or older-aged groups were analyzed separately. A few reasons are suggested for this discrepancy. First, several of the teeth affected were too loose to be retained, and the remaining teeth were relatively healthy in the older-aged group; thus, the relationship between the two was difficult to confirm.

The second reason that might explain why the association could be more pronounced among younger than older adults was the confounding metabolic changes in later life, such as high triglycerides, which might have weakened the actual relationship. Additionally, the high risk for systemic disease in older age might have prompted subjects to seek medical advice more frequently, resulting in more active prevention and treatment of various diseases such that the real relationship was masked. The third reason was that the small sample size was not sufficient to represent the older age group. Thus, the real relationship between obesity and periodontitis in older aged subjects requires further research.

Decades earlier, it was noted that obesity could aggregate the severity of periodontitis in rats [15]. The correlation between obesity and severity of periodontitis was suggested and investigated in recent studies.
Relationships between obesity and periodontal diseases, including BMI and waist-to-hip ratio and various periodontal measures such as mean periodontal attachment, mean pocket depth, and mean gingival bleeding index were studied by Wood et al. [26]. Deep periodontal pockets, obvious attachment loss, bleeding upon probing, and plaque accumulation were more commonly seen in the obese and subjects with a BMI >35 kg/m$^2$ had a higher proportion of Tannerella forsythia in their flora composition [27]. This study found that the average PD, average AL, and percentages of sites with PD ≥4 mm, PD ≥6 mm, Al ≥1 mm, and Al ≥3 mm were significantly higher in overweight and obese subjects ($P$<0.05) compared with participants with BMI <24 kg/m$^2$. Additionally, all of the periodontal parameters, including the average PD, average AL, and the percentages of sites with PD≥4 mm, PD ≥6 mm, Al ≥1 mm, Al ≥3 mm, and Al ≥5 mm, were significantly higher among subjects with abdominal obesity ($P$<0.05). BMI-defined obesity and high WC were suggested to not only be significantly associated with increased odds of having periodontitis but also with the severity and extent of the periodontitis. More body fat, which meaning more adipose tissue and reservoir for inflammatory cytokines, might actively participate in the development of insulin resistance and progression of periodontitis.

The underlying biological mechanisms for the association between obesity and periodontitis are not well known. The adverse effects of obesity could be mediated through several mechanisms, including impaired glucose tolerance, dyslipidemia, impaired immune response, and secretion of substances from adipose tissue [28]. Adipose tissue, though assumed to chiefly be a triglycerides reservoir, is more exactly an important metabolic endocrine organ, especially visceral adipose tissue. Plenty of immunomodulatory factors are secreted by this endocrine system and dominated in regulating metabolic and vascular biology.

Adipose cells, which include adipocytes, preadipocytes, and macrophages, secrete more than 50 bioactive molecules known as adipocytokines, which may in turn affect the periodontal tissues [29-31]. Pro-inflammatory cytokines such as TNF-α, IL-6, IL-1β, and $PGE_2$ can activate osteoclasts and collagen enzymes, which stimulate bone absorption and promote degradation of the connective tissue matrix destroying the bone and periodontium [29, 32, 33]. In addition, obesity increases the host's susceptibility by modulating the host's immune and inflammatory systems, leaving the subject with a greater risk of periodontitis and other chronic diseases.

Although this study showed a relationship between abdominal obesity and periodontitis, some limitations must be highlighted. First, the sample used for the study was small and was taken from only one geographic area, which was insufficient to represent the whole nation of China. Second, using cross-sectional data makes it impossible to determine the direction of causal relationships. This positive association was consistent with a biologically plausible role for obesity in the development of periodontal disease. However, with few well-designed longitudinal studies, there is an inability to distinguish the temporal ordering of events, thereby limiting the evidence that obesity is a risk factor for periodontal disease or that periodontitis might increase the risk of weight gain. In clinical practice, a higher prevalence of periodontal disease should be expected among obese adults [34].

The direction of the relationship might also be opposite to the one expected, or it might be bidirectional. Longitudinal studies with more precise measures of adiposity and laboratory studies will provide better insights into the relationship between periodontal disease and obesity. The third limitation is that the effects of other residual confounders could not be completely eliminated, and we did not consider dietary habits such as consumption of foods or beverages high in sugars, or lifestyles, although these have an impact on periodontal status.

In conclusion, abdominal obesity was significantly associated with an increased prevalence, severity, and extent of periodontitis in a Chinese population, but there was no significant association among older-aged subjects. The underlying biological mechanisms for the associations are not well known, and additional research is needed to determine the nature of this association.

**Conflict of Interest**

The authors declare that they have no competing interest.

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