The relationship between different types of caries and periodontal disease severity in middle-aged and elderly people: findings from the 4th National Oral Health Survey of China

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Abstract

Background: The relationship between dental caries and periodontal disease is still controversial. The objective of this study is to explore the relationship between different types of caries and periodontal disease severity in middle-aged and elderly people in China.

Methods: The study population consisted of 4,387 middle-aged and 3,225 elderly subjects. Caries were divided into the following three types: type A, crown caries; type B, lesions involving both the crown and root, representing a mixed type; and type C, root caries. These three types together represent the overall caries situation, which we call type ABC. Caries were quantitated by decayed and filled teeth (DFT index). Periodontitis was evaluated by clinical attachment loss.

Results: Middle-aged people with periodontitis had a significant association with DFT of type ABC (OR: 1.09, 95% CI: 1.06-1.11), type A (OR: 1.05, 95% CI: 1.02-1.08), type B (OR: 1.20, 95% CI: 1.16-1.28) and type C (OR: 1.36, 95% CI: 1.15-1.60). Elderly people with periodontitis had a significant association with DFT of type ABC (OR: 1.05, 95% CI: 1.03-1.07), type B (OR: 1.07, 95% CI: 1.05-1.10) and type C (OR: 1.30, 95% CI: 1.19-1.42) but not type A.

Conclusions: Different types of caries in middle-aged people and overall caries and caries types involving the root surface in elderly people were significantly associated with periodontal disease severity.

Background

Dental caries and periodontitis are the most common diseases in the oral cavity among adults. Both diseases are the primary cause of tooth loss and can lead to negative impacts on the quality of life. To date, the relationship between the two diseases is still controversial. Although several studies have shown a positive correlation between the two diseases [1-10], some studies have shown a negative correlation [11-13] or no association [14].

The reasons for the positive correlation include common social-behavioural factors, such as age, gender, poor oral hygiene, smoking status, etc. [15]. In addition, evidence suggests that host genetic factors play a moderate role in caries and periodontitis [15]. The main reason for the inverse correlation is different bacteriological spectrum. Accumulating evidence suggests that *Streptococcus mutans* is the primary cariogenic bacterium, while periodontitis is associated with specific gram-negative anaerobic bacteria, such as *Porphyromonas gingivalis*. A negative association has been reported between salivary levels of *S. mutans* and *P. gingi*valis in subjects with varying severities of caries and periodontitis, indicating that an inverse correlation exists between the two diseases [13].

Caries can be divided into the following three types according to the location of occurrence: crown caries, root caries and mixed type caries affecting both the crown and root. According to the instructions by the WHO, if a carious lesion involves both the crown and the root, the possible site of origin of the carious lesion should be recorded as the site of decay. When it is impossible to determine the origin of the lesion,

both the crown and root should be recorded as decayed [16]. In fact, in a large-scale oral epidemiological examination, it was very difficult to confirm the origin of caries in most cases. Therefore, it is difficult to classify caries involving both the crown and root as coronal caries or root caries. To the best of our knowledge, regarding the relationship between the two diseases, few studies have been able to clearly identify the specific types of caries studied [1, 7]. It has been noted that the detection methods of caries could be a plausible explanation for the discrepancies found in the relationship between caries and periodontitis [12]. Due to the controversial relationship between the two diseases, it is necessary to classify caries.

Inconsistencies in subject selection could be another plausible explanation for the discrepancies found between the two diseases [12]. It has been noted that studies reporting an inverse association between the two diseases are mostly based on selected patients who constitute a young population no older than 20 years with juvenile periodontitis, who have been recognized as having increased susceptibility to periodontitis [14]. Similar to many diseases, age is an important factor that has a greater impact than other known risk factors on caries and periodontitis that can explain the variation in occurrence. The role of age in both diseases has been attributed to accumulated exposure. In addition, a recent study showed that susceptibility to the two diseases could change with ageing [17].

Taken together, the relationship between dental caries and periodontal disease is still controversial. No large sample studies investigated the relationship between these two diseases in the Chinese population. The objective of this study is to explore the relationship between different types of caries and periodontal disease severity while considering different types of caries in middle-aged and elderly people from the 4th National Oral Health Survey in China. As caries and periodontitis are related to many social and behavioural background factors, an ordered logistic regression was used to control for relevant confounders.

Methods

Sampling and clinical examination method

The present study was a part of the 4th National Oral Health Survey, which is the most comprehensive oral health survey to date in China and was carried out in 2015-2016. Multistage stratified sampling method was used to recruit adults from all 31 provinces, municipalities and autonomous regions in mainland China. The probability proportional to size (PPS) method was used to randomly select subjects [18]. In total, 4,410 35- to 44-year-olds and 4,431 65- to 74-year-olds completed the survey. The exclusion criteria for this analysis were participants who had fewer than 20 teeth [3, 19] and a periodontal status that could not be examined for any reason, such as non-standard fixed prosthesis that cover the gingiva or the presence of calculus to such an extent that a periodontal examination is impossible.

The latest WHO recommendations (2013) with appropriate adjustments according to the actual situation were used for the clinical oral examinations. The examinations were conducted by three trained licensed

dentists, while three other trained individuals with clinical experience acted as recorders in each province. The examinations were conducted with a mobile dental chair using artificial light, a disposable dental mirror, and a standard WHO Community Periodontal Index (CPI) probe [18].

Variables

Independent variables

Caries were recorded for all tooth surfaces, but the observations were recorded by tooth. We divided caries into the following three types: type A, caries or a filling on the crown, representing crown caries; type B, caries or a filling involving both the crown and root, representing the mixed type; and type C, caries or a filling on the root, representing root caries. These three types together represent the overall caries situation, which we call type ABC (Figure 1). Because residual roots involve both the crown and root, we classified residual roots as type B. Missing teeth of any cause were recorded as code 5 in adults in our national survey which was different from the WHO recommendations. The number of decayed and filled teeth (DFT) was calculated to analyse its relationship with periodontitis. The kappa values of the inter-examiners' reliabilities in the examination of dental caries were 0.97 in both the middle-aged and elderly groups [18, 20].

Dependent variables

Periodontal disease severity was evaluated by clinical attachment loss (CAL) by tooth. A full mouth examination was performed, including the third molars. The tooth with the worst CAL score was recorded for the person-level score. Probing was performed by "walking around" along gingival crevices with a standardized force of no more than 20 grams. Each tooth was recorded according to its severity. CAL was scored as 0 (0-3 mm), 1 (4 -5 mm), 2 (6-8 mm), 3 (9 -11 mm), 4 (12 mm or more), 9 (tooth excluded) or X (tooth not present). For the analysis, periodontitis was divided into the following three groups according to CAL: ≤3 mm, 4-5 mm, and ≥6 mm. Before the field investigation, the examiners underwent training, and each examiner and reference examiner performed an examination of 10 to 15 subjects per group to assess their consistency. The kappa value was calculated to be greater than 0.6, suggesting good reliability [18].

Covariates

The covariates included in the statistical analysis were social economic status (SES), such as gender (female or male), area (urban or rural), education level (≤12 years or >12 years), and household income per capita (less than RMB 5,000/person, RMB 5,000 to RMB 15,000/person, more than RMB 15,000/person, or prefer not to answer); oral health-related behaviours, such as frequency of dessert consumption (<twice a day or ≥twice a day), frequency of tooth brushing (<once per day or ≥once per day), use of dental floss (no or yes), use of toothpicks (no or yes), smoking status (never or current), and alcohol consumption (ceased, rarely/never, daily, or weekly); and diabetes history (no or yes) [21, 22].

Statistical analysis

The data analysis was carried out using SPSS 20.0. Chi-square was performed to compare periodontitis according to the participant characteristics. To determine the association between periodontitis and dental caries, ordinal logistic regression models were used. First, a bivariate analysis was performed. Then, the independent variables with $P \leq 0.25$ based on the bivariate logistic analysis were further tested in the multivariate analysis. Three ordinal logistic regression models were constructed to measure the crude and adjusted effects of the DFT scores on periodontitis. In Model 1, the DFT scores were introduced as the only independent variable. Then, in Model 2, the DFT scores and SES were included. Finally, the DFT scores, SES, oral health-related behaviours and diabetes were included in Model 3. A P-value<0.05 in all two-sided statistical tests was considered significant. The statistical analyses did not include missing values or individuals who preferred not to answer.

Results

In total, 4,410 subjects aged 35-44 years and 4,431 subjects aged 65-74 years completed the national survey. Participants who had fewer than 20 teeth were excluded as follows: subjects aged 35-44 years: n=22 (0.5%) and subjects aged 65-74 years: n=1172 (26%). The participants were excluded if their periodontal status could not be examined for any reason as follows: subjects aged 35-44 years: n=1 (0.02%) and subjects aged 65-74 years: n=34 (1.0%). Finally, a sample of 4,387 subjects aged 35-44 years and 3,225 subjects aged 65-74 years were included in the analysis (Figure 2).

Table 1 shows the results of the bivariate analysis of the characteristics of the participants in relation to their periodontal status in the 35- to 44-year-old group. We found that gender, area, education level, household income per capita, tooth brushing frequency, use of dental floss, use of toothpicks, frequency of dessert consumption, smoking status, drinking alcohol and diabetes were associated with periodontal disease severity ($P \leq 0.25$). Table 2 shows the results of the bivariate analysis of the characteristics of the participants in relation to their periodontal status in the 65- to 74-year-old group. We found that gender, area, household income per capita, tooth brushing frequency, use of toothpick, frequency of dessert consumption, smoking status and drinking alcohol were associated with periodontal disease severity ($P \leq 0.25$).

Covariates with $P \leq 0.25$ were included in the ordered logistic regression. The primary outcome was the severity of periodontitis with CAL≤3 mm as the reference category. Table 3 shows the association between the number of DFT and periodontal disease severity in the 35- to 44-year-old group. Adults with periodontitis had a significant association with DFT of type ABC (OR: 1.09, 95% CI: 1.06-1.11), type A (OR: 1.05, 95% CI: 1.02-1.08), type B (OR: 1.20, 95% CI: 1.16-1.28) and type C (OR: 1.36, 95% CI: 1.15-1.60). Table 4 shows the association between the number of DFT and periodontal disease severity in the 65- to 74-year-old group. Elderly people with periodontitis had a significant association with DFT of type ABC (OR: 1.05, 95% CI: 1.03-1.07), type B (OR: 1.07, 95% CI: 1.05-1.10) and type C (OR: 1.30, 95% CI: 1.19-1.42) but not type A (OR: 0.98, 95% CI: 0.95-1.02, P=0.319).

Discussion

The present study explored the relationship between different types of caries and periodontal disease severity in middle-aged and elderly people in a nationally sample in China. We discuss the relationship between the two diseases by age group because the risk factors, susceptibility to both diseases, and especially the number and causes of missing teeth in different age groups are different. Because bivariate analyses cannot exclude confounders related to periodontitis, ordered logistic regression models were used. We found that different types of caries in middle-aged people and overall caries and the caries types involving the root surface in elderly people were significantly associated with periodontal disease severity. To the best of our knowledge, this study is the first to analyse the relationship between caries and periodontal disease in a national sample of Chinese adults.

There are some potential limitations in this study that should be addressed. First, due to the cross-sectional data used in this study, the causal relationship between caries and periodontitis cannot be determined. Second, we were obligated to identify periodontitis using CAL instead of definitions of periodontitis, such as that described by the Centers for Disease Control and Prevention and the American Academy of Periodontology (CDC–AAP). Third, the exclusion criteria of fewer than 20 teeth may have rendered the age group of elderly people less representative. Fourth, people who could be treated for periodontal disease could be a confounder. Fifth, the present study only considered decayed and filled teeth as a caries experience, which may not reflect the actual caries experience as this definition excludes missing teeth due to caries. Sixth, pairing individuals or teeth in this type of research is ideal, which is a significant limitation of this study.

The criteria commonly used to define periodontitis include the probing depth (PD) and CAL. The PD reflects the current situation of periodontitis, and CAL reflects the long-term accumulation of periodontal damage. Because caries and periodontitis are long-term chronic destructive diseases, the past cumulative lifetime experience of periodontitis is reflected by CAL measurements. Therefore, it is recommended to use this measure to analyse the risk factors of periodontitis in epidemiological studies [23].

Previous studies concerning the relationship between caries and periodontitis have rarely clearly described whether the caries studied was crown caries, root caries, or mixed type caries. In recent years, two articles clearly defined the types of caries studied, i.e., one study investigated crown/root caries [1], and the other study investigated crown caries [7]. Some studies have noted that when we encounter type B caries, we do not know whether to classify it as crown caries or root caries. This issue is a measurement issue more than a diagnostic issue [24]. The relationship between caries and periodontitis in different locations of caries may be different; thus, we divided the types of caries in this way to further understand the relationship between caries and periodontitis.

We found that all four caries types (ABC/A/B/C) were positively correlated with periodontitis in the middle-aged group, and three caries types (ABC/B/C) were positively correlated with periodontitis in the elderly group. Previously, few articles discussed the relationship between the two diseases according to different age groups. Some studies report that a positive correlation exists between caries and

periodontal disease severity in adults. Al Qobaly et al. found that individuals aged 35 years or older with periodontitis had a higher risk of coronal and root caries in England, Northern Ireland and Wales [1]. Hyman et al. reported that untreated coronal caries surfaces in US individuals aged 20 years or older were positively correlated with the mean CAL [7]. Mattila et al. reported a positive association between PD and the DT index in Finnish adults aged 30 years and older [6]. Strauss et al. reported a positive association between periodontitis and the DT index among Chilean adults aged between 35 and 44 years [2]. This positive association could be explained by the common socioeconomic status they share. The socioeconomic status seems to influence relevant health behaviours, such as diet, oral hygiene, smoking and patterns of seeking professional prevention or treatment [15]. In our analysis, gender, area, smoking status, tooth brushing frequency and household income per capita were significantly associated with periodontitis in both age groups. To the best of our knowledge, both caries and periodontal diseases are bacterial infectious diseases. Although the microbiological profiles of the two diseases are different, poor oral hygiene is considered a main common risk factor, which could provide enough fermentable carbohydrates for bacterial reproduction and subsequently increase the prevalence of the two diseases [1, 15]. In addition, smoking has been proven to be another important health behaviour that is a common risk factor for both diseases [15]. Furthermore, it has been demonstrated that host genetics plays a moderate role in contributing to the susceptibility to both caries and periodontal disease. Although no common genetic genes have been found, pleiotropy (one gene influences two or more seemingly unrelated phenotypic traits) in caries and periodontal disease may exist. Hence, regarding the role of genetics, more analyses of pleiotropy are needed to unravel the mechanism and better understand the genetic association between caries and periodontal disease accumulating in the same person [15].

Type A caries were shown to have no relationship, but types B and C were positively associated with periodontitis in the elderly group in our study. In the middle-aged group, the DFT index increased with the aggravation of periodontitis, while in the elderly, the group with the most severe CAL (≥6 mm) had the lowest DFT. Tooth loss may be a cause. With an increase in age, the tooth loss rate of the elderly significantly increases, and the most frequent occurrence of tooth extraction due to periodontitis should be in the group with CAL≥6 mm. However, because of the nature of this cross-sectional study, we could not investigate the specific reasons for tooth extraction. Carious lesions of both types B and C involve the root surface. Periodontal attachment loss could lead to the exposure of the root surface. As a result of poor oral hygiene, root caries commonly presents as a progressive lesion in patients with periodontitis [25]. The positive correlation between types B and C caries and periodontitis is consistent with a recent systemic review. Root caries incidence or increment has been reported to be associated with patients having periodontal disease [17].

Taken together, to draw a conclusion regarding the association between caries and periodontitis, longitudinal studies are needed. Because the susceptibility to the two diseases could change with ageing. Future research should be conducted in different age groups using a similar methodology such that the results could be compared. It has been reported that using toothpicks is a risk factor and that using dental floss is a protective factor for CAL in the 35- to 44-year-old group in China [21]. This finding is probably because the wrongful use of toothpicks could increase the risk of periodontal damage [21]. In

this study, we could observe that in both age groups, nearly half of the participants use toothpicks, and only a few people use dental floss. Additionally, the brushing rate in both age groups was high, close to 90%; however, whether the correct brushing method was adopted was unclear. Hence, to address these two common oral diseases, public health policies should be adopted to promote public awareness of oral health care, develop good oral hygiene habits, such as mastering correct tooth-brushing methods, regular flossing, oral examinations and timely dental scaling.

Conclusions

A positive association between different caries types and periodontal disease severity was found in middle-aged people in China. Except for crown caries, overall caries and the caries types involving the root surface were positively associated with periodontal disease severity in elderly people. This study provides epidemiologic support for the relationship between these two diseases. This study suggests that better public health policies should be adopted to promote public awareness of oral health care and develop good oral hygiene habits.

List Of Abbreviations

CAL: Clinical attachment level; CDC–AAP: Center for Disease Control and Prevention and the American Academy of Periodontology; CPI: Community Periodontal Index; DFT: Decayed and filled teeth; PD: Probing depth; PPS: Probability proportional to size; WHO: World Health Organization

Declarations

Ethics approval and consent to participate

This study was approved by the Stomatological Ethics Committee of the Chinese Stomatological Association (Approval no. 2014-003). Written informed consent was obtained from each participant.

Consent for publication

Not applicable.

Availability of data and materials

The datasets analysed in this study are available from the corresponding authors upon reasonable request.

Competing interests

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

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Author contributions

YLX contributed to the data analysis and preparation of the manuscript. WX, FXP, TBJ, HDY, WB, WCX, ZSG, LXN, RWS, WWJ, SY and LHC trained the investigators and designed and supervised the survey. SY and LHC contributed to the design of the study, general supervision of the research group, and critically revised the manuscript for important intellectual content. All authors read and approved the final version of the manuscript.

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References

1. AlQobaly L, Sabbah W. The association between periodontal disease and root/coronal caries. Int J Dent Hyg. 2019;18(1):99-106.
2. Strauss F, Espinoza I, Stähli A, Baeza M, Cortés R, Morales A, Gamonal J. Dental caries is associated with severe periodontitis in Chilean adults: a cross-sectional study. BMC oral health. 2019;19(278).
3. Durand R, Roufegarinejad A, Chandad F, Rompré PH, Voyer R, Michalowicz BS, Emami E. Dental caries are positively associated with periodontal disease severity. Clin Oral Investig. 2019;23(10):3811-9.
4. Nascimento GG, Baelum V, Dahlen G, Lopez R. Methodological issues in assessing the association between periodontitis and caries among adolescents. Community Dent Oral Epidemiol. 2018;46(3):303-9.
5. Zimmermann H, Hagenfeld D, Diercke K, El-Sayed N, Fricke J, Greiser KH, et al. Pocket depth and bleeding on probing and their associations with dental, lifestyle, socioeconomic and blood variables: a cross-sectional, multicenter feasibility study of the German National Cohort. BMC oral health. 2015;15(7).
6. Mattila PT, Niskanen MC, Vehkalahti MM, Nordblad A, Knuuttila ML. Prevalence and simultaneous occurrence of periodontitis and dental caries. J Clin Periodontol. 2010;37(11):962-7.
7. Hyman JJ, Reid BC. Epidemiologic risk factors for periodontal attachment loss among adults in the United States. J Clin Periodontol. 2003;30(3):230-7.

8. Elter JR, Beck JD, Slade GD, Offenbacher S. Etiologic models for incident periodontal attachment loss in older adults. J Clin Periodontol. 1999;26(2):113-23.
9. Albandar JM, Brown LJ, Löe H. Dental caries and tooth loss in adolescents with early-onset periodontitis. J Periodontol. 1996;67(10):960-7.
10. Albandar JM, Buischi YA, Axelsson P. Caries lesions and dental restorations as predisposing factors in the progression of periodontal diseases in adolescents. A 3-year longitudinal study. J Periodontol. 1995;66(4):249-54.
11. Al-Habashneh R, Al-Omari MA, Taani DQ. Smoking and caries experience in subjects with various form of periodontal diseases from a teaching hospital clinic. Int J Dent Hyg. 2009;7(1):55-61.
12. Sioson PB, Furgang D, Steinberg LM, Fine DH. Proximal caries in juvenile periodontitis patients. J Periodontol. 2000;71(5):710-6.
13. Iwano Y, Sugano N, Matsumoto K, Nishihara R, Iizuka T, Yoshinuma N, Ito K. Salivary microbial levels in relation to periodontal status and caries development. J Periodontal Res. 2010;45(2):165-9.
14. Kinane DF, Jenkins WM, Adonogianaki E, Murray GD: Cross-sectional assessment of caries and periodontitis risk within the same subject. Community Dent Oral Epidemiol. 1991;19(2):78-81.
15. Chapple ILC, Bouchard P, Cagetti MG, Campus G, Carra M, Cocco F, et al. Interaction of lifestyle, behaviour or systemic diseases with dental caries and periodontal diseases: consensus report of group 2 of the joint EFP/ORCA workshop on the boundaries between caries and periodontal diseases. J Clin Periodontol. 2017;44(Suppl 18):S39-S51.
16. WHO. Oral health surveys: Basic methods. 5th ed. Geneva: World Health Organization; 2013.
17. López R, Smith PC, Göstemeyer G, Schwendicke F. Ageing, dental caries and periodontal diseases. J Clin Periodontol. 2017;44(Suppl 18):S145-S52.
18. Lu HX, Tao DY, Lo ECM, Li R, Wang X, Tai BJ, et al. The 4th National Oral Health Survey in the Mainland of China: Background and Methodology. Chin J Dent Res. 2018;21(3):161-5.
19. Guo J, Ban JH, Li G, Wang X, Feng XP, Tai BJ, et al. Status of Tooth Loss and Denture Restoration in Chinese Adult Population: Findings from the 4th National Oral Health Survey. Chin J Dent Res. 2018;21(4):249-57.
20. Gao YB, Hu T, Zhou XD, Shao R, Cheng R, Wang GS, et al. Dental Caries in Chinese Elderly People: Findings from the 4th National Oral Health Survey. Chin J Dent Res. 2018;21(3):213-20.
21. Sun HY, Jiang H, Du MQ, Wang X, Feng XP, Hu DY, et al. The Prevalence and Associated Factors of Periodontal Disease among 35 to 44-year-old Chinese Adults in the 4th National Oral Health Survey. Chin J Dent Res. 2018;21(4):241-7.
22. Wang CX, Ma LL, Yang Y, Xu MR, Wang X, Feng XP, et al. Oral Health Knowledge, Attitudes, Behaviour and Oral Health Status of Chinese Diabetic Patients Aged 55 to 74 Years. Chin J Dent Res. 2018;21(4):267-73.
23. Tonetti MS, Claffey N. Advances in the progression of periodontitis and proposal of definitions of a periodontitis case and disease progression for use in risk factor research - Group C Consensus report

of the 5th European workshop in periodontology. J Clin Periodontol. 2005;32(Suppl 6):S210-S3.
24. Banting DW. The diagnosis of root caries. J Dent Educ. 2001; 65(10):991-6.
25. Bignozzi I, Crea A, Capri D, Littarru C, Lajolo C, Tatakis DN. Root caries: a periodontal perspective. J Periodontal Res. 2014;49(2):143-63.

Tables

Table 1 Bivariate analysis of the participant characteristics in relation to their periodontal status in the 35 to 44-year-old group.

Variables	Overall n	Degree of periodontitis			*P*-value [a]
		CAL≤3mm	CAL=4-5mm	CAL≥6mm	
Total	4387(100.0)	2938(67.0)	1118(25.5)	331(7.5)	
Socioeconomic characteristics					
Gender(%)					<0.001
Female†	2202(50.2)	1599(54.4)	501(44.8)	102(30.8)	
Male	2185(49.8)	1339(45.6)	617(55.2)	229(69.2)	
Area (%)					<0.001
Urban†	2227(50.8)	1545(52.6)	508(45.4)	174(52.6)	
Rural	2160(49.2)	1393(47.4)	610(54.6)	157(47.4)	
Educational level(%)					<0.001
≤12 years†	3171(72.3)	2027(69.0)	876(78.4)	268(81.0)	
>12 years	1215(27.7)	910(31.0)	242(21.6)	63(19.0)	
Household income per capita(%)					<0.001
Less than RMB 5,000/person†	922(21.0)	551(18.7)	277(24.8)	94(28.4)	
RMB5,000 to RMB 15,000/person	1396(31.8)	946(32.2)	341(30.5)	109(32.9)	
More than RMB 15,000/person	1386(31.6)	980(33.4)	318(28.4)	88(26.6)	
Prefer not to answer [c]	683(15.6)	461(15.7)	182(16.3)	40(12.1)	
Oral health-related behaviors					
Tooth brushing frequency(%)					<0.001
<Once per day†	292(6.7)	135(4.6)	113(10.1)	44(13.3)	
≥Once per day	4095(93.3)	2803(95.4)	1005(89.9)	287(86.7)	
Use of dental floss(%)					<0.001
No†	4156(94.7)	2755(93.8)	1081(96.8)	320(96.7)	
Yes	230(5.2)	183(6.2)	36(3.2)	11(3.3)	
Use of toothpick(%)					<0.001
No†	2383(54.3)	1676(57.0)	563(50.4)	144(43.5)	
Yes	2004(45.7)	1262(43.0)	555(49.6)	187(56.5)	
Frequency of dessert consumption(%)					0.156
<Twice a day†	4289(97.8)	2864(97.5)	1101(98.5)	324(97.9)	
≥Twice a day	98(2.2)	74(2.5)	17(1.5)	7(2.1)	
Smoking status(%)					<0.001
Never†	2937(67.0)	2077(70.8)	684(61.2)	176(53.2)	
Current(former)	1448(33.0)	859(29.2)	434(38.8)	155(46.8)	
Drinking alcohol(%)					0.019
Ceased†	115(2.6)	68(2.3)	32(2.9)	15(4.5)	
Rarely/never	3692(84.1)	2509(85.4)	922(82.5)	261(78.9)	
Daily	204(4.6)	128(4.4)	58(5.2)	18(5.4)	
Weekly	373(8.5)	230(7.8)	106(9.5)	37(11.2)	
Missing values [b]	3(0.1)	3(0.1)	0(0.00)	0(0.0)	
Systemic diseases associated with periodontitis					
Diabetes(%)					<0.001
No†	4302(98.0)	2894(98.5)	1094(97.9)	314(94.9)	
Yes	85(2.0)	44(1.5)	24(2.1)	17(5.1)	

[a] Chi-square test, [b,c] Statistical analyses did not include missing values and individuals who preferred not to answer.
†Reference
Covariates with $P \leq 0.25$ were included in the ordered logistic regression.

Table 2 Bivariate analysis of the participant characteristics in relation to their periodontal status in the 65 to 74-year-old group.

Variables	Overall n	Degree of periodontitis			*P*-value[a]
		CAL≤3mm	CAL=4-5mm	CAL≥6mm	
Total	3225(100.0)	728(22.6)	1202(37.3)	1295(40.2)	
Socioeconomic characteristics					
Gender(%)					<0.001
Female†	1615(50.1)	427(58.7)	642(53.4)	546(42.2)	
Male	1610(49.9)	301(41.3)	560(46.6)	749(57.8)	
Area (%)					0.040
Urban†	1700(52.7)	413(56.7)	612(50.9)	675(52.1)	
Rural	1525(47.3)	315(43.3)	590(49.1)	620(47.9)	
Educational level(%)					0.452
≤12 years†	3009(93.3)	673(92.4)	1121(93.3)	1215(93.9)	
>12 years	215(6.7)	55(7.6)	81(6.7)	79(6.1)	
Household income per capita(%)					0.040
Less than RMB 5,000/person†	923(28.6)	176(24.2)	360(29.9)	387(29.9)	
RMB5,000 to RMB 15,000/person	792(24.6)	196(26.9)	280(23.3)	316(24.4)	
More than RMB 15,000/person	902(28.0)	216(29.7)	334(27.8)	352(27.2)	
Prefer not to answer [c]	608(18.9)	140(19.2)	228(19.0)	240(18.5)	
Oral health-related behaviors					
Tooth brushing frequency(%)					<0.001
<Once per day†	495(15.3)	81(11.1)	184(15.3)	230(17.8)	
≥Once per day	2730(84.7)	647(88.9)	1018(84.7)	1065(82.2)	
Use of dental floss(%)					0.365
No†	3156(97.9)	710(97.5)	1173(97.6)	1273(98.3)	
Yes	69(2.1)	18(2.5)	29(2.4)	22(1.7)	
Use of toothpick(%)					0.131
No†	1423(44.1)	341(46.8)	507(42.2)	575(44.4)	
Yes	1802(55.9)	387(53.2)	695(57.8)	720(55.6)	
Frequency of dessert consumption(%)					0.237
<Twice a day†	3174(98.4)	717(98.5)	1188(98.8)	1269(98.0)	
≥Twice a day	51(1.6)	11(1.5)	14(1.2)	26(2.0)	
Smoking status(%)					<0.001
Never†	2050(63.6)	510(70.1)	818(68.1)	722(55.8)	
Current(former)	1175(36.4)	218(29.9)	384(31.9)	573(44.2)	
Drinking alcohol(%)					0.030
Ceased†	280(8.7)	53(7.3)	106(8.8)	121(9.3)	
Rarely/never	2514(78.0)	589(80.9)	955(79.5)	970(74.9)	
Daily	299(9.3)	60(8.2)	98(8.2)	141(10.9)	
Weekly	131(4.1)	26(3.6)	43(3.6)	62(4.8)	
Missing values [b]	1(0.0)	0(0.0)	0(0.0)	1(0.1)	
Systemic diseases associated with periodontitis					
Diabetes(%)					0.948
No†	2817(87.3)	634(87.1)	1049(87.3)	1134(87.6)	
Yes	408(12.7)	94(12.9)	153(12.7)	161(12.4)	

[a] Chi-square test, [b,c] Statistical analyses did not include missing values and individuals who preferred not to answer.
†Reference
Covariates with $P \leq 0.25$ were included in the ordered logistic regression.

Table 3 The association between the number of teeth with dental caries and

periodontal disease severity in the 35 to 44-year-old group.

DFT (mean±SD)	Degree of periodontitis			Model 1 [a]	Model 2 [b]	Model 3 [c]
	CAL≤3mm N=2938	CAL=4-5mm N=1118	CAL≥6mm N=331	*P*-value and OR (95% CI)	*P*-value and OR (95% CI)	*P*-value and OR (95% CI)
Type ABC	1.92±2.69	2.40±3.08	2.91±3.42	<0.001 1.07(1.05,1.10)	<0.001 1.09(1.07,1.11)	<0.001 1.09 (1.06, 1.11)
Type A	1.52±2.22	1.66±2.32	1.67±2.18	0.044 1.03(1.00,1.06)	0.001 1.05 (1.02, 1.08)	0.001 1.05 (1.02, 1.08)
Type B	0.37±1.13	0.69±1.55	1.11±2.10	<0.001 1.25(1.19,1.30)	<0.001 1.23 (1.18, 1.29)	<0.001 1.20 (1.16, 1.28)
Type C	0.03±0.28	0.05±0.41	0.13±0.62	<0.001 1.40(1.18,1.65)	<0.001 1.39(1.17, 1.64)	<0.001 1.36 (1.15, 1.60)

[a] Model 1: DFT was included as the only independent variable for the analysis by ordered logistic regression.

[b] Model 2: Social economic status such as gender, area, education level, household income per capita were added to Model 1.

[c] Model 3: Oral health-related behaviors such as smoking status, tooth brushing frequency, use of dental floss, use of toothpick, drinking alcohol, frequency of dessert consumption and diabetes were added to Model 2.

Table 4 The association between the number of teeth with dental caries and periodontal disease severity in the 65 to 74-year-old group.

DFT (mean±SD)	Degree of periodontitis			Model 1 [a]	Model 2 [b]	Model 3 [c]
	CAL≤3mm N=728	CAL=4-5mm N=1202	CAL≥6mm N=1295	*P*-value and OR (95% CI)	*P*-value and OR (95% CI)	*P*-value and OR (95% CI)
Type ABC	3.35±4.26	4.00±4.28	4.30±4.49	<0.001 1.03(1.02,1.05)	<0.001 1.05(1.04,1.07)	<0.001 1.05(1.03,1.07)
Type A	1.46±2.19	1.53±2.10	1.24±1.80	0.003 0.95(0.92,0.98)	0.276 0.98(0.94,1.02)	0.319 0.98(0.95,1.02)
Type B	1.76±3.35	2.18±3.25	2.65±1.15	<0.001 1.06(1.04,1.08)	<0.001 1.07(1.05,1.10)	<0.001 1.07(1.05,1.10)
Type C	0.13±0.57	0.29±1.05	0.41±1.15	<0.001 1.23(1.14,1.33)	<0.001 1.30(1.19,1.42)	<0.001 1.30(1.19,1.42)

[a] Model 1: DFT was included as the only independent variable for the analysis by ordered logistic regression.

[b] Model 2: Social economic status such as gender, area, household income per capita were added to Model 1.

[c] Model 3: Oral health-related behaviors such as smoking status, tooth brushing frequency, use of toothpick, drinking alcohol, frequency of dessert and consumption were added to Model 2.

Figures

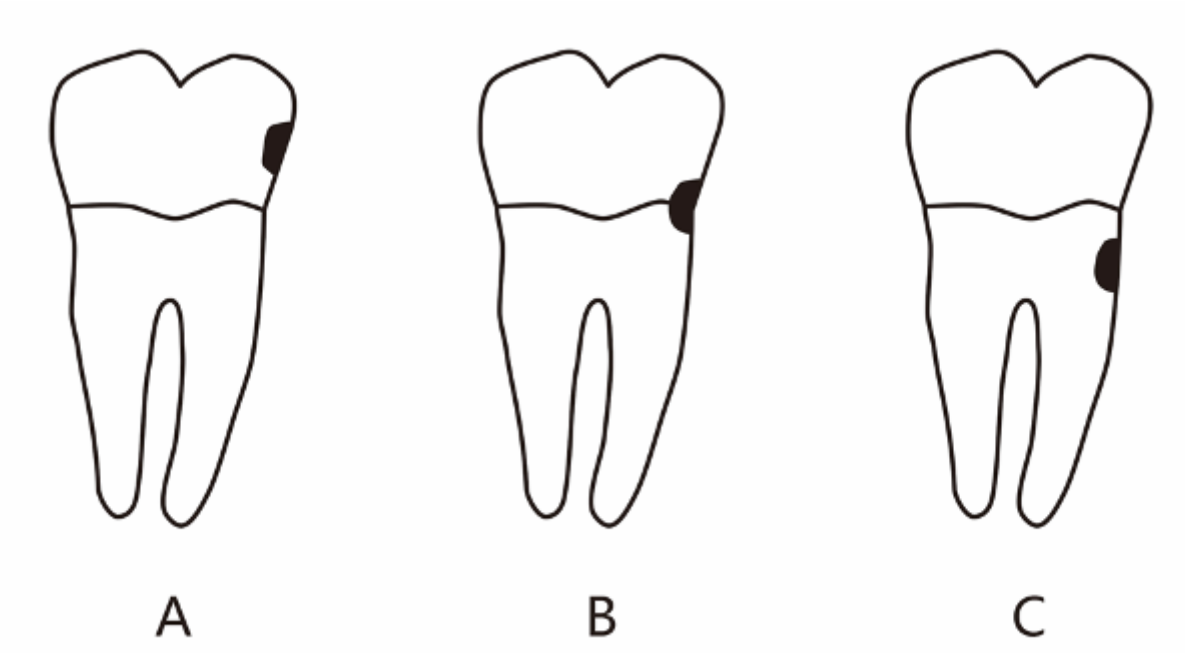

Figure 1

Types of dental caries divided according to the occurrence location. Legends: Type A, caries or a filling on the crown, representing crown caries. Type B, caries or a filling involving both the crown and root, representing mixed type caries. Type C, caries or a filling on the root, representing root caries. These three types together represent the overall caries situation, which we call type ABC.

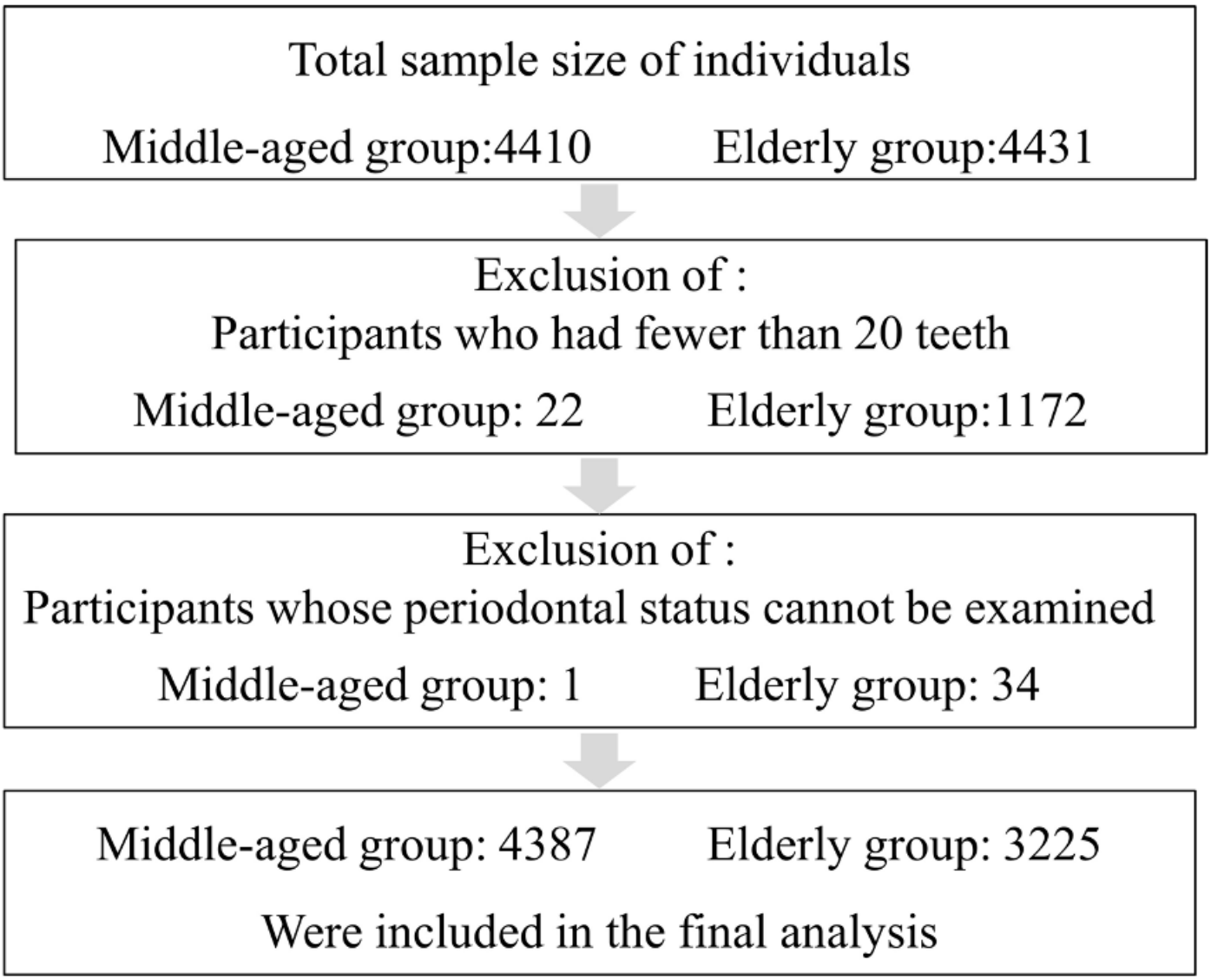

Figure 2

Flow chart of data collection.