Original Article

Epidemiology of periodontal disease in adolescents in mainland China, 1983–2020: a systematic review and meta-analysis

Li Xiao[1,2,3,4], Kalen Karapen[1,2,3], Shi Dong[1,2,3], Hongmei Yang[1,2,3], Xiaonan Zhang[1,2,3]

[1]College of Stomatology, Chongqing Medical University, Chongqing, China; [2]Chongqing Key Laboratory of Oral Diseases and Biomedical Sciences, Chongqing, China; [3]Chongqing Municipal Key Laboratory of Oral Biomedical Engineering of Higher Education, Chongqing, China; [4]The First Affiliated Hospital of Chongqing Medical University, Chongqing, China

Contributions: (I) Conception and design: L Xiao, X Zhang; (II) Administrative support: X Zhang; (III) Provision of study materials or patients: S Dong; (IV) Collection and assembly of data: S Dong, K Karapen; (V) Data analysis and interpretation: L Xiao, H Yang; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Xiaonan Zhang. College of Stomatology, Chongqing Medical University, Chongqing, China, No. 426 Songshibei Road, Yubei District, Chongqing, China. Email: zhangxiaonan@hospital.cqmu.edu.cn.

Background: Periodontal disease is a chronic inflammatory disease that includes primarily gingivitis and periodontitis, caused by bacterial infection of the supporting structures of the teeth. For years, much attention has been diverted to periodontal disease among the elderly, not enough attention is paid to adolescents. The purpose of this meta-analysis is to evaluate the epidemic trend of periodontal disease in adolescents in mainland China.

Methods: We conducted a comprehensive literature search through PubMed, Embase, CNKI, Chongqing VIP database, Chinese Wan Fang Database, and CBM. A series of subgroup analyses were done to explore the epidemiological characteristics of periodontal disease (gender, location, age, survey year, and geographical distribution) with the help of related software.

Results: Thirty studies were included in this study. The data extraction and analysis were from three indexes, including bleeding on probing (BOP), pocket depth (PD), and dental calculus (DC). The detection rates of BOP(+), PD ≥4 mm and DC(+) were 48.8% (95% CI: 36.2–61.4%), 1.0% (0.0–2.0%), and 49.8% (41.0–58.6%), respectively. There were significant differences for the prevalence of gingivitis both in gender and area: the prevalence was higher in males than that in females, and risk ratio was 1.04 (95% CI, 1.01–1.06); a lower prevalence in urban areas compared with rural areas, and the risk ratio was 0.90 (95% CI, 0.85–0.96).

Conclusions: This study shows a high prevalence of gingivitis among adolescents in China. Higher-quality epidemiological surveys with standard examination criteria are needed.

Keywords: Epidemiology; periodontal disease; adolescents; systematic review

Submitted Aug 17, 2020. Accepted for publication Dec 23, 2020.
doi: 10.21037/apm-20-1919
View this article at: http://dx.doi.org/10.21037/apm-20-1919

Introduction

Periodontal disease is a chronic inflammatory disease that includes primarily gingivitis and periodontitis, caused by bacterial infection of the supporting structures of the teeth (1). For years, much attention has been diverted to periodontal disease among the elderly (2,3), not enough attention is paid to adolescents. However, periodontal disease is among the most common diseases affecting adolescents (4). Gingivitis in adolescents may remain for a more extended period with the symptom of gingival bleeding, and it may gradually lead to the progression of periodontitis. However, according to WHO Global Oral Health Data Bank, the occurrence of periodontal disease is high among older children and adolescents, with 50% to 100% of 12-year-old children having the signs of gum inflammation (5), this suggests a

risk of periodontal disease among the adolescent population. Periodontal disease may have negative effects on oral health, chewing function, and aesthetics, and the physical and mental health of adolescents (6). Also, it has been reported that periodontal disease may influence the severity of malocclusion in adolescents (7,8).

Earlier studies have reported the different disease burden of periodontal diseases among adolescents worldwide. For instance, the prevalence of chronic periodontitis among 15–19 years old in Asia differs, including 0% in India (9) and 6% in Japan (10); a higher prevalence in Africa, which includes Algeria (13%) (11), Egypt (17%) (11) and Nigeria (56%) (11). As for gingivitis among the adolescents aged 15, the prevalence rates varied according to national oral health surveys in different countries, ranging from 30% in Greek (12), 16% in the United Arab Emirates (13), and 52% in the United Kingdom of Great Britain and Northern Ireland (14). China is the most populous country in the world, with a vast territory, considerable differences in income, and traditions. The total population of adolescents was around 174 million in 2010, adding up to 13.11% of the national population (15). Several studies have reported the prevalence of the periodontal disease in adolescents in mainland China, which showed a significant difference. For instance, the reported prevalence of gingivitis at age 15 years was about 5.75% in Heilongjiang (16), while 87.6% in Hubei (17). These differences may be because of different survey sites, survey methods, and diagnostic criteria.

There are no systematic reviews on the prevalence of the periodontal disease in adolescents in mainland China. Therefore, adolescents aged 10–19 years were selected for this study (18). We analyzed the epidemiological characteristics of periodontal disease in adolescents from all cross-sectional studies in this meta-analysis to explore the prevalence trend with time, gender, age, and geography. These results may supply valuable information to prevent periodontal disease and implementing relevant oral health policies for adolescents.

We present the following article in accordance with the PRISMA reporting checklist (available at http://dx.doi.org/10.21037/apm-20-1919).

Methods

Search strategy

A comprehensive electronic search was conducted in PubMed and Embase and Chinese databases, including the Chinese National Knowledge Infrastructure Database (CNKI), Chongqing VIP database, Chinese Biomedical Literature Database (CBM), and Chinese Wan Fang Database, by two independent authors. The electronic search was conducted for articles from commencement to 2 February 2020, using the key terms 'periodontitis', 'periodontal disease,' 'prevalence,' 'incidence,' 'epidemiology,' 'epidemiologic,' 'China' and 'Chinese.' Also, a manual search was done for potential literature to avoid the loss of information.

Literature selection

All screening procedures and reporting of this meta-analysis followed the guidance of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (19). The two authors reviewed the titles and abstracts of relevant literature independently, and full-text articles of the potentially available literature were analyzed. Discrepancies were resolved by discussion or by the third author, and Cohen's Kappa values were used to determine the agreement level between the reviewers (20).

Inclusion criteria: the articles selected in this study were according to the following inclusion criteria; (I) surveys done in mainland China (except Hong Kong, Taiwan, and Macao); (II) participants within the age of 10–19 years old; (III) the survey areas were city-level or above; (IV) studies containing adequate information for diagnosing periodontal disease and calculating the relative prevalence; (V) articles published in English or Chinese; (VI) studies with the random sampling method.

Exclusion criteria: the articles excluded were: (I) studies carried out on particular population or areas; (II) survey sites below city-level; (III) study population younger than ten years old and older than 19 years old; (IV) repeated literature; (V) low-quality literature, secondary studies or irrelevant studies.

Data extraction

Two authors carried out the data extraction independently, and the following data were extracted: survey year, regional level, survey location, age range, sampling methods, methods and criteria used for diagnosis, number of samples, and cases (total, males or females, urban or rural). All data were from the detection rates of dental calculus (DC)(+), bleeding on probing (BOP)(+), and pocket depth (PD) ≥4 mm. The Community Periodontal Index of Treatment Needs (CPITN) or Community Periodontal Index (CPI) examination

retrieved the measured variables in most of the studies. Other studies did not show the examination performance method. Two extraction sheets were also completed independently by the two investigators to confirm the accuracy and feasibility of the data extraction. Disagreements were resolved by consensus or by the third author.

Quality assessment

The qualities of the included studies were assessed by applying the 'Strengthening the Reporting of Observational Studies in Epidemiology (STROBE)' statement (21) (Table S1). Six items were used in the STROBE checklist, which included evaluations of the title and abstract, introduction, methods, results, discussion, and other information. The checklist was assessed independently by the two investigators, and an agreement was reached, or the third author was consulted when necessary.

Data analysis

The pooled detection rates and 95% confidence intervals (CI) for each indicator were estimated via R software version 3.3.3. I^2-statistics was applied to explore the statistical heterogeneity across the included studies. A random-effects model was selected if the heterogeneity was significant (I^2>50% or P<0.05). When there was less heterogeneity, a fixed-effects model was adopted. A series of subgroup analyses were done by two authors to explore the relationship between the detection rates with some factors, including gender, age, and location. R software version 3.3.3 and STATA software 16.0 were combined to calculate relative risk (RR) and 95% CI to compare discrepancies. Graph Pad Prism was used to describe the trends within different periods (≤1990, 1991–1995, 1995–2000, 2001–2005, 2006–2010, and ≥2011) or the different ages (12, 15, 18 years old). SuperMap GIS software 2.0 was used to present the regional distribution of detection rates. Funnel plots and Begg's test estimated publication bias. The level of statistical significance was set at 0.05. Sensitivity analysis was performed to detect effects on conclusions of statistical analysis by eliminating each study.

Results

Literature selection and quality assessment

A preliminary result of 5,922 studies were identified, including PubMed (n=537), Embase (n=385), CNKI (n=1,345), the Wan Fang Database (n=1,549), the Chongqing VIP Database (n=1,147), and CBM (n=959). Subsequently, 3,050 studies were excluded after adjustment of duplicates, and 2,109 studies were discarded after browsing the titles and the abstracts. After examining the full texts of 763, 314 studies on special populations or the surveys were conducted in special areas; 13 survey sites are below city-level; 2 did not report survey data; 34 did not report survey site and survey time; 296 did not report age clearly, or age was younger than 11, or age was older than 20; 45 literatures are low quality; 29 did not relevant. From the 763 full-text articles retrieved, only 30 studies met the eligibility criteria (*Figure 1*) and were included in this review. Of the 30 included studies, 4 epidemiological surveys (16,22-24), 25 were published in Chinese (17,25-48), and only one was in English (49). These articles included three national level, seven provincial-level, and 20 city-level. The Kappa values for titles and abstracts screening was 0.864, and for full-text evaluation was 0.804 (Tables S2,S3).

The detailed characteristics of the 30 included studies are presented in *Table 1*. Twenty-one articles followed random sampling, while the others do not mention the sampling methods. Professional dentists and medical students were recruited as examiners in 19 studies and were trained to achieve unified criteria of examination methods and diagnostic indexes.

There were different diagnostic criteria in the included studies (*Table 1*). The diagnostic indexes were with BOP, DC, and PD. The examination methods also differed, in which 22 studies used the CPITN (50) or CPI (51). In these methods, only six index teeth (11,16,26,31,36,46) are examined, and the results of PD in participants under 15 years old are not recorded to avoid the false periodontal pocket formed during the eruption of permanent teeth (52). One study examined all the teeth of the subjects, and seven studies did not indicate the examination methods used.

The Strobe checklist estimated quality assessment, and 32 listed items scored each study/sub-items. The results showed favorable outcomes and were of acceptable quality (Table S4).

Detection rates of BOP(+)

Twenty-six studies reported the detection rates of BOP(+), and the detection rate was 48.8% (95% CI: 36.2–61.4%).

BOP(+) detection rates by gender. Detection rates of BOP(+) by gender was indicated in21articles. The detection

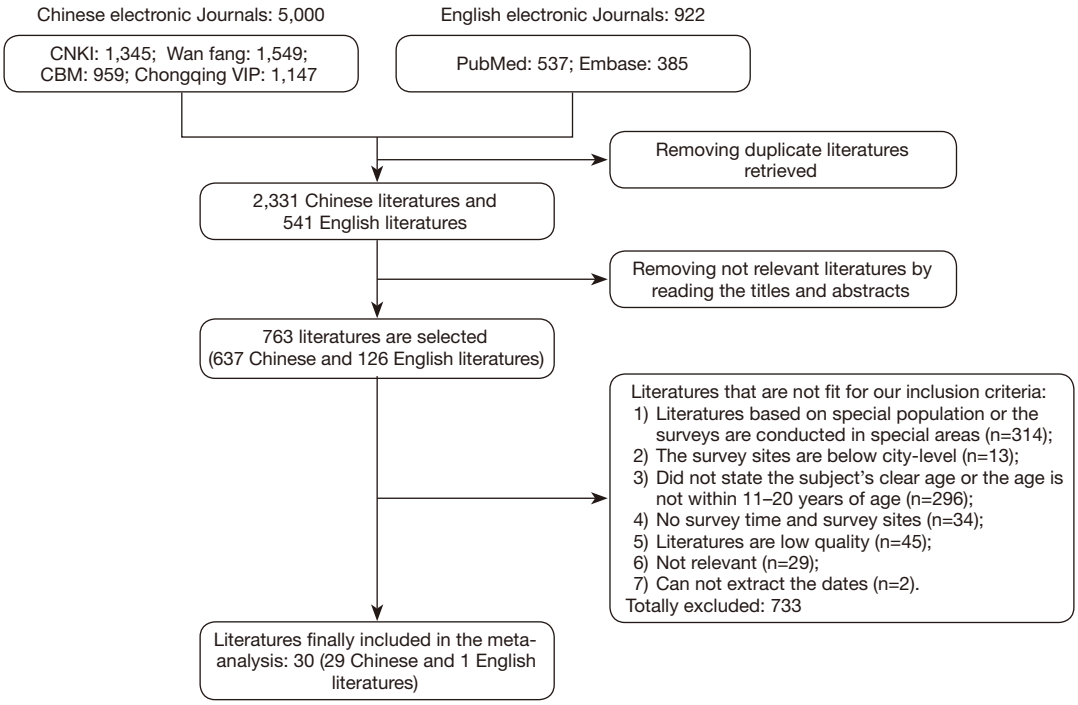

Figure 1 Flow chart showing the meta-analysis studies selection.

rates in males was 51.0% (95% CI: 35.9–66.1%) while in females was 48.7% (95% CI: 34.7–62.8%, *Table 2*). A significant result revealed that the detection rate of BOP(+) in males was higher than that in females (RR =1.04, 95% CI: 1.01–1.06, *Figure 2A*).

BOP(+) detection rates by location. 12 studies reported BOP(+) both in urban and rural areas. Respectively, the pooled detection rates in urban and rural areas were 46.4% (95% CI: 32.0–60.8%) and 46.3% (95% CI: 28.1–64.5%, *Table 2*). The detection rate of BOP(+) in urban areas was lower than that in rural areas (RR =0.90, 95% CI: 0.85–0.96, *Figure 2B*).

BOP(+) detection rates with survey year. *Table 2* shows the pooled detection rates of BOP(+) for surveys done in ≤1995, 1995–2000, 2001–2005, 2006–2010 and ≥2011 were 82.2% (95% CI: 39.4–100.0%), 47.0% (95% CI: 26.2–67.9%), 35.7% (95% CI: 11.0–60.4%), 46.3% (95% CI: 22.0–70.6%) and 44.8% (95% CI: 25.4–64.3%), respectively. No significant trend is reflected from 1983 to 2020 (*Figure 2C*).

BOP(+) detection rates by age group. The detection rate of BOP(+) was 53.2% (95% CI: 36.7–69.7%) in adolescents aged 12 as reported in 12 studies. Eleven studies reported the detection rates for aged 15, while the detection rates for the 18 years old were shown in six studies. The results were 39.8% (95% CI: 21.5–58.0%) and 36.2% (95% CI: 12.1–60.3%) respectively. We observed a decreasing trend of prevalence with individuals aged from 12 to 18.

Detection rates of PD ≥4 mm

The pooled estimated detection rate of PD in 13 studies (15–19 years old) conducted from 1983 to 2020 was 1.0% (95% CI: 0.0–2.0%), as shown in *Table 2*. PD ≥4 mm detection rates by gender. 12 studies reported the detection rates in males and the pooled detection rate was 1.0% (95% CI: 0.0–3.0%), while the pooled detection rate was 1.0% (95% CI: 0.0–3.0%, *Table 2*). The results show no difference in subgroup analysis with gender (RR =1.05, 95% CI: 0.97–1.13, *Figure 3A*).

PD ≥4 mm detection rates by location. The detection rates in urban areas were reported in 11 studies, while three studies were reported for rural areas. Respectively, the detection rates of PD ≥4 mm in urban areas were 1.0% (95% CI: 0.0–3.0%), and 2.0% (95% CI: 0.0–8.0%, *Table 2*) in rural areas. Statistically, no significant difference was shown in these two groups by area (RR =0.95, 95% CI: 0.83–1.08, *Figure 3B*).

PD ≥4 mm detection rates with survey year. The detection rates of PD ≥4 mm during 2001–2005 were not available, and the detection rates in ≤1995, 1996–2000,

Table 1 Characteristics of the included 30 studies

Study	Survey year	Provinces	Territorial levels	U&R	Sampling method	Diagnostic criteria	Examination method	Age	Sample case	Case size		
										BOP(+)	PD ≥4 mm	DC(+)
Bao *et al.* (17)	2011	Heilongjiang	Provincial	U&R	Multistage stratified random	Guideline for the 3rd National Oral Health Survey	CPI	15	1,200	69	NA	133
Jiang *et al.* (18)	2005	Hubei	Provincial	U&R	Random	Guideline for the 2nd National Oral Health Survey	CPI	12	1,080	887	NA	715
								15	1,080	946	NA	870
								12, 15	2,160	1,833	NA	1,585
NCOH (22)	1995	China	Country	U&R	Multi-stage stratified cluster	Guideline for the 2nd National Oral Health Survey	CPI	12	23,452	8,921	NA	12,202
								15	23,452	8,191	53	15,627
								18	23,452	7,624	163	18,431
								12, 15, 18	70,356	24,736	216	46,260
NCOH (23)	2005	China	Country	U&R	Multi-stage stratified cluster	Guideline for the 3rd National Oral Health Survey	CPI	12	23,508	13,564	NA	13,875
NCOH (24)	2015	China	Country	U&R	Multi-stage stratified cluster	Guideline for the 4th National Oral Health Survey	CPI	12	27,821	16,248	NA	17,045
								15	29,128	18,837	1901	21,433
								12–15	118,601	72,344	NA	79,821
Hu *et al.* (25)	2000	Shanghai	City	U	NA	Baer	CPI	11–13	2,605	532	4	608
								14–16	3,560	1,280	21	1,356
								17–19	3,383	1,741	48	2,024
								11–19	9,548	3,553	73	3,988
Wang *et al.* (26)	1988	Beijing	City	U	NA	Baer	NA	11–15	3,706	NA	11	NA
								14–18	4,660	NA	24	NA
								15–19	1,641	NA	8	NA
								11–19	10,007	NA	43	NA
Tan *et al.* (27)	1993	Heilongjiang	City	U	NA	Baer	NA	11–13	595	NA	8	NA
								12–16	264	NA	4	NA
								15–20	749	NA	12	NA
								11–19	1,608	NA	24	NA

Table 1 *(continued)*

Table 1 *(continued)*

Study	Survey year	Provinces	Territorial levels	U&R	Sampling method	Diagnostic criteria	Examination method	Age	Sample case	Case size		
										BOP(+)	PD ≥4 mm	DC(+)
Li *et al.* (28)	1995	Zhejiang	City	U&R	Non-proportional stratified cluster	Guideline for the 2nd National Oral Health Survey	CPI	12	720	588	0	353
								15	720	643	0	495
								18	720	684	0	565
								12, 15, 18	2,160	1,915	0	1,413
Cheng *et al.* (29)	2009	Liaoning	City	U	Multistage and equal capacity random	Guideline for the 3rd National Oral Health Survey	All the teeth	15	480	153	12	358
Li *et al.* (30)	2000	Henan	City	U	NA	Guideline for the 2nd National Oral Health Survey	CPI	12	155	NA	0	6
								15	151	NA	0	72
								18	163	NA	0	104
								12, 15, 18	469	NA	0	182
Zhang *et al.* (31)	1999	Jiangsu	City	U	NA	Guideline for the 2nd National Oral Health Survey	CPI	11–13	11,300	8,512	48	4,052
								15–17	9,281	6,791	54	4,168
								11–17	20,581	15,303	102	8,220
Ding (32)	1983	Sichuan	City	U&R	NA	WHO oral health survey	NA	12	120	95	NA	78
								17	120	113	1	112
Wan *et al.* (33)	1990	Sichuan	Provincial	U&R	NA	Oral Medicine	CPITN	12–13	660	656	NA	645
Tian *et al.* (34)	1999	Guizhou	City	U&R	Non-proportional stratified cluster	WHO oral health survey	CPITN	12	1,100	306	NA	490
								15	1,100	257	8	567
								18	1,100	231	13	621
								12, 15, 18	3,300	794	21	1,678
Duan *et al.* (35)	1999	Beijing	City	U	Random	WHO oral health survey	CPITN	13	1,292	617	NA	714
								14	1,339	614	NA	801
								15	206	91	NA	137
								16	995	517	NA	650
								17	1,030	484	NA	677
								18	294	132	NA	199
								13–18	5,156	2,455	NA	3,178
Lei *et al.* (36)	2000	Fujian	Provincial	U&R	Stratified cluster	WHO oral health survey	CPI	15	2,132	1,108	155	895

Table 1 *(continued)*

Table 1 *(continued)*

Study	Survey year	Provinces	Territorial levels	U&R	Sampling method	Diagnostic criteria	Examination method	Age	Sample case	Case size		
										BOP(+)	PD ≥4 mm	DC(+)
Lin and Li (37)	2002	Chongqing	City	U&R	Stratified cluster	WHO oral health survey	CPI	12	3,145	55	NA	476
								15	2,386	33	NA	731
								18	2,797	53	NA	1,419
								12, 15, 18	8,328	141	NA	2,626
Wu *et al.* (38)	2003	Shanxi	City	U&R	Random	WHO oral health survey	CPI	12–18	3,132	991	NA	1,101
Liao *et al.* (39)	2003	Hunan	City	U&R	Cluster	WHO oral health survey	NA	15	4,768	120	NA	216
Wu *et al.* (40)	2006	Jiangsu	City	U	NA	WHO oral health survey	CPI	12–18	16,056	4325	NA	5,210
Xie *et al.* (41)	2007	Guizhou	Provincial	U&R	Random	WHO oral health survey	NA	12	1,000	582	NA	451
Liu *et al.* (42)	2009	Shandong	City	U	NA	WHO oral health survey	NA	12, 15, 18	3,080	2363	28	2,146
Yang and Li (43)	2009	Shandong	City	U&R	Random	Gingivitis: no abnormality in the color, shape, and texture of the gums	NA	15–16	1,518	571	NA	NA
Liu *et al.* (44)	2011	Hebei	City	U	Multi-stage stratified cluster	Guideline for the 3rd National Oral Health Survey	CPI	13–15	528	353	NA	NA
								15–18	535	399	NA	NA
								13–18	1,063	752	NA	NA
Bi *et al.* (45)	2011	Heilongjiang	Provincial	U&R	Multistage stratified random	Guideline for the 3rd National Oral Health Survey	CPI	18	1,200	263	NA	348
Chen *et al.* (46)	2015	Beijing	City	U	Stratified cluster	Guideline for the 3rd National Oral Health Survey	CPI	12	364	NA	NA	130
Liu *et al.* (47)	2015	Zhuhai	City	U	Multistage cluster	WHO oral health survey	CPI	12	633	235	NA	NA
Lin *et al.* (48)	2015	Guangzhou	City	U&R	Multistage cluster	WHO oral health survey	CPI	12	1,405	992	NA	413
Yin *et al.* (49)	2015	Sichuan	Provincial	U&R	Multistage cluster	WHO oral health survey	CPI	12	4,573	2,136	NA	3,057

NCOH, National Committee for Oral Health; NA, not available; U, urban; R, rural; WHO, World Health Organization; BOP, bleeding on probing; PD, pocket depth; DC, dental calculus.

Table 2 Pooled detection rates of BOP(+), PD ≥4 mm, and DC(+) in mainland China during 1983–2020

Group	BOP(+)				PD ≥4 mm				DC(+)			
	Number of surveys	Sample size	Cases	Prevalence (%) (95% CI)	Number of surveys	Sample size	Cases	Prevalence (%) (95% CI)	Number of surveys	Sample size	Cases	Prevalence (%) (95% CI)
Overall	26	306,838	171,389	48.8 (36.2–61.4)	13	153,089	2,576	1.0 (0.0–2.0)	25	304,447	178,052	49.8 (41.0–58.6)
Location												
Urban	19	187,491	77,623	46.4 (32.0–60.8)	11	95,493	523	1.0 (0.0–3.0)	20	196,027	108,127	46.7 (37.0–55.6)
Rural	12	107,732	54,333	46.3 (28.1–64.5)	4	39,284	1,091	2.0 (0.0–8.0)	20	108,444	70,042	46.4 (32.2–60.6)
Gender												
Male	21	140,090	73,493	51.0 (35.9–66.1)	12	76,113	1,313	1.0 (0.0–3.0)	21	138,886	87,698	53.4 (46.9–60.0)
Female	21	139,525	71,275	48.7 (34.7–62.8)	12	76,760	1,262	1.0 (0.0–3.0)	13	138,351	81,462	52.1 (44.8–59.4)
Time periods												
≤1995	4	73,416	27,155	82.2 (39.4–100)	5	84,371	284	0.0 (0.0–1.0)	4	26,568	16,123	75.3 (52.3–98.4)
1996–2000	5	40,717	23,213	47.0 (26.2–67.9)	5	36,030	351	1.0 (0.0–3.0)	6	41,176	18,141	45.9 (38.7–53.1)
2001–2005	5	41,896	16,649	35.7 (11.0–60.4)	0	NA	NA	NA	5	41,896	19,403	40.7 (13.9–67.6)
2006–2010	5	22,134	7,994	46.3 (22.0–70.6)	2	3,560	40	1.6 (0.0–3.1)	4	20,616	8,165	55.4 (31.9–78.9)
≥2011	7	128,675	76,791	44.8 (25.4–64.3)	1	29,128	1,901	6.5 (6.2–6.8)	6	127,343	83,902	39.9 (19.9–60.0)
Age												
12	12	88,557	44,609	53.2 (36.7–69.7)	NA	NA	NA	NA	13	88,443	49,291	45.6 (37.4–53.7)
15	11	66,652	30,448	39.8 (21.5–58.0)	7	57,163	2,129	2.6 (0.4–4.8)	12	66,803	41,534	51.5 (31.7–71.3)
18	6	29,563	8,987	36.2 (12.1–60.3)	4	25,435	176	0.0 (0.0–1.0)	7	29,726	21,687	60.7 (44.9–76.4)

BOP, bleeding on probing; PD, pocket depth; DC, dental calculus; CI, confidence interval; NA, not available.

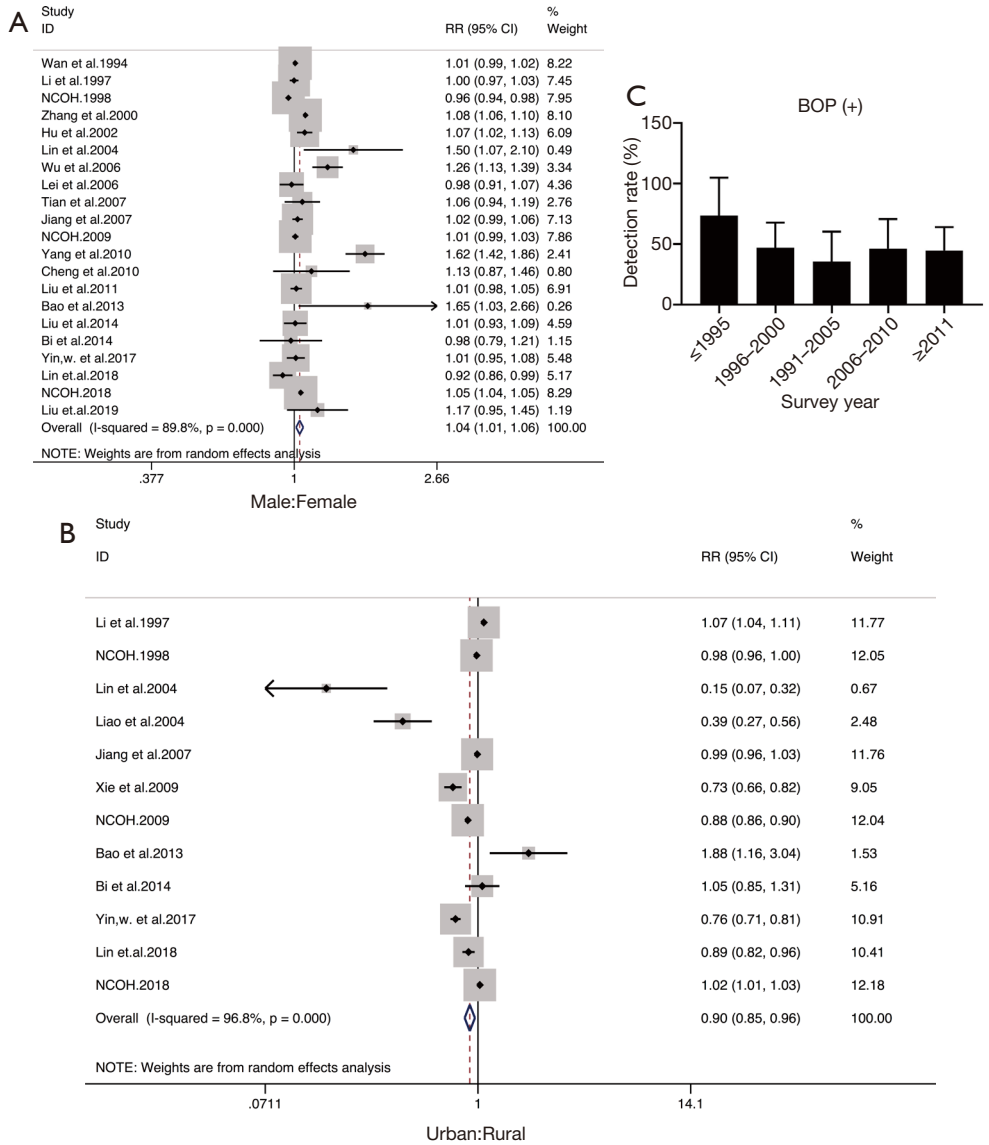

Figure 2 The detection rates of BOP among adolescents in mainland China during 1983–2020. BOP, bleeding on probing.

2006–2010 and 1996 were 0.0% (95% CI: 0.0–1.0%), 1.0% (95% CI: 0.0–3.0%), 1.6% (95% CI: 0.0–3.1%) and 6.5% (95% CI: 6.2–6.8%). An increasing trend is observed from 1983 to 2020 (*Figure 3C*).

PD ≥4 mm detection rates by age group. The detection rates of PD were 2.6% (95% CI: 0.4–4.8%) in adolescents at age 15 and 0.0% (95% CI: 0.0–1.0%) at age 18. There is no significant trend with age from 15 to 18 years old.

Detection rates of DC(+)

Twenty-five publications reported DC detection rates, and the pooled detection rate was 49.8% (95% CI: 41.0–58.6%).

DC(+) detection rates by gender. 20 studies showed detection rates by gender, in which 53.4% (95% CI: 46.9–60.0%) in males and 52.1% (95% CI: 44.8–59.4%, *Table 2*) in females. There were no obvious statistical differences in these two groups (RR =1.03, 95% CI: 0.98–1.07, *Figure 4A*).

DC(+) detection rates by location. As shown in *Table 2*, 21 studies reflected the detection rates of DC(+) in urban areas and 13 studies in rural areas. The detection rates in urban and rural areas were 46.7% (95% CI: 37.9–55.6%, *Table 2*) and 46.4 % (95% CI: 32.2–60.6%, *Table 2*), respectively. There was a slight difference between urban

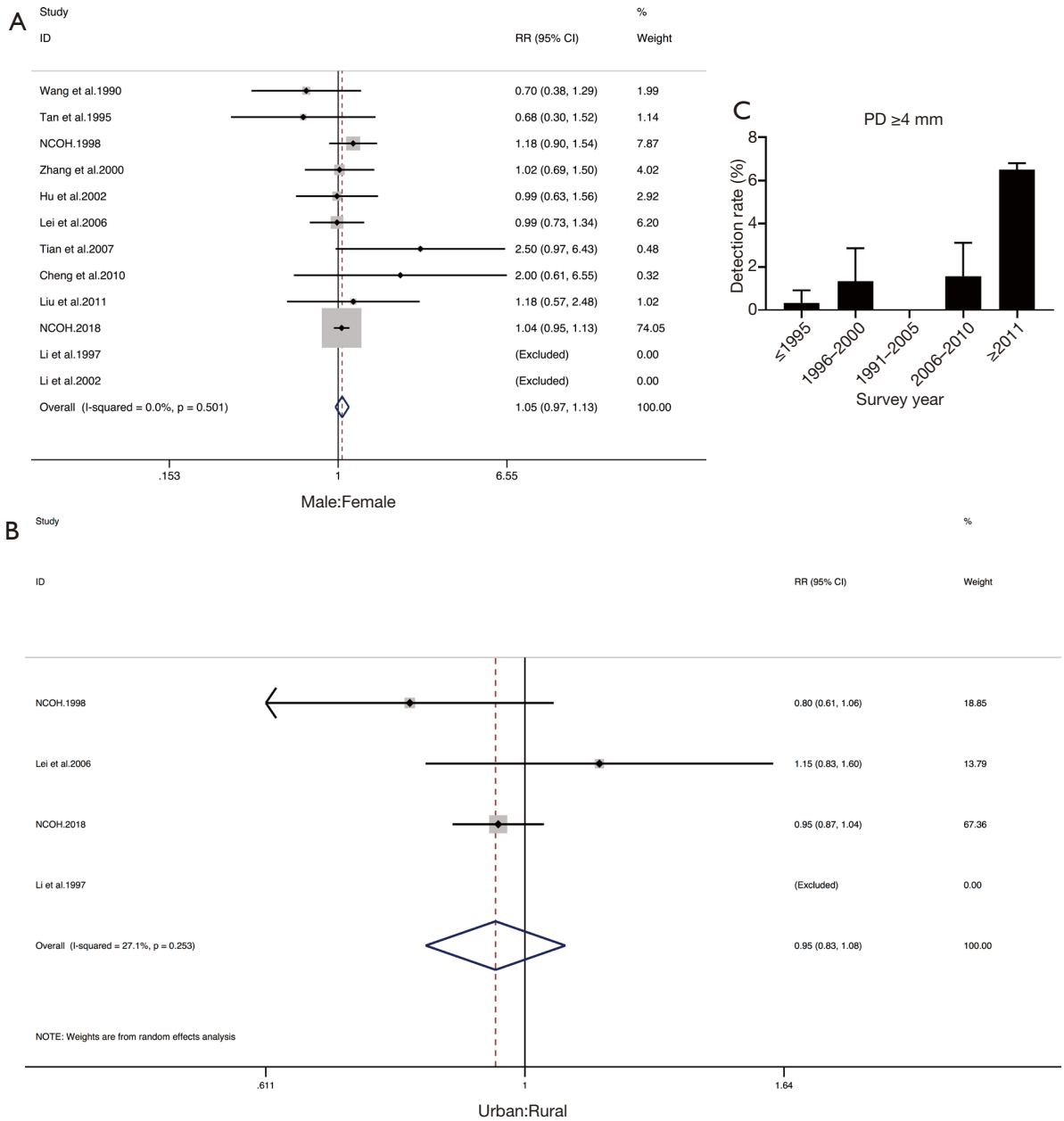

Figure 3 The detection rates of PD among adolescents in mainland China during 1983–2020. PD, pocket depth.

and rural areas (RR =0.96, 95% CI, 0.91–1.02) (*Figure 4B*).

DC(+) detection rates from survey year. *Table 2* shows the pooled detection rates of DC(+) in surveys done in ≤1995, 1995–2000, 2001–2005, 2006–2010 and ≥2011 were 75.3% (95% CI: 52.3–98.4%), 45.9% (95% CI: 38.7–53.1%), 40.7% (95% CI: 13.9–67.6%), 55.4% (95% CI: 31.9–78.9%), and 39.9% (95% CI: 19.9–60.0%), respectively. The detection rate of DC in adolescents reflects a fluctuating trend from 1983 to 2020 (*Figure 4C*).

DC(+) detection rates by age group. The detection rates of DC were 45.6% (95% CI: 37.4.4–53.7%) at aged 12, 51.5% (95% CI: 31.7–71.3%) at aged 15, and 60.7% (95% CI: 44.9–76.4%) at aged 18, respectively. The result reflects an elevated rate as age increases.

Regional distribution of detection rates in mainland China

The color-coded map in *Figure 5* illustrates the distribution

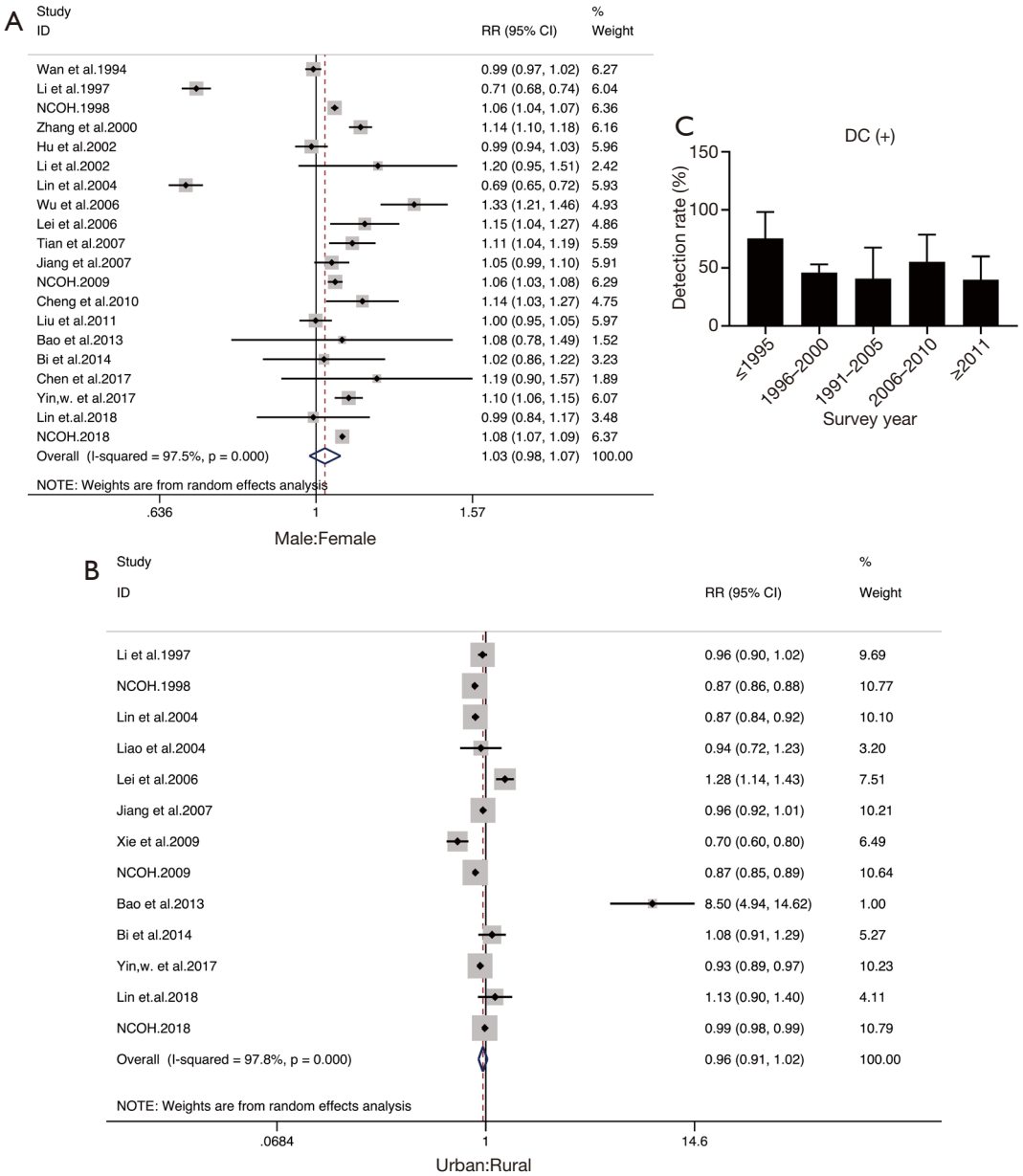

Figure 4 The detection rates of DC among adolescents in mainland China during 1983–2020. DC, dental calculus.

of the detection rates of BOP(+), PD ≥4 mm, and DC(+) in mainland China, respectively (except Tibet). Five distribution zones on the map with distinct colors were created. The first level shows that there is no available data in the relevant regions and is white on the map. The second to fourth levels are arranged by detection rate from low to high, and the color on the map is from light to deep. The highest detection rate is shown at the highest level, which is dark red on the map. The detection rates of BOP(+) ranged from 98.6% in Qinghai to 11.3% in Yunnan. The detection rate of PD ≥4 mm was highest in Fujian (7.2%) and lowest in Hunan (0.0%). The detection rates of DC had significant differences in various regions, ranging from 89.4% in Qinghai to 37.4% in Heilongjiang. No features in the distribution of BOP(+), PD ≥4 mm, and DC(+) detection rates are presented on the map.

Publication bias and sensitivity test

The funnel plots show publication bias, and the results of

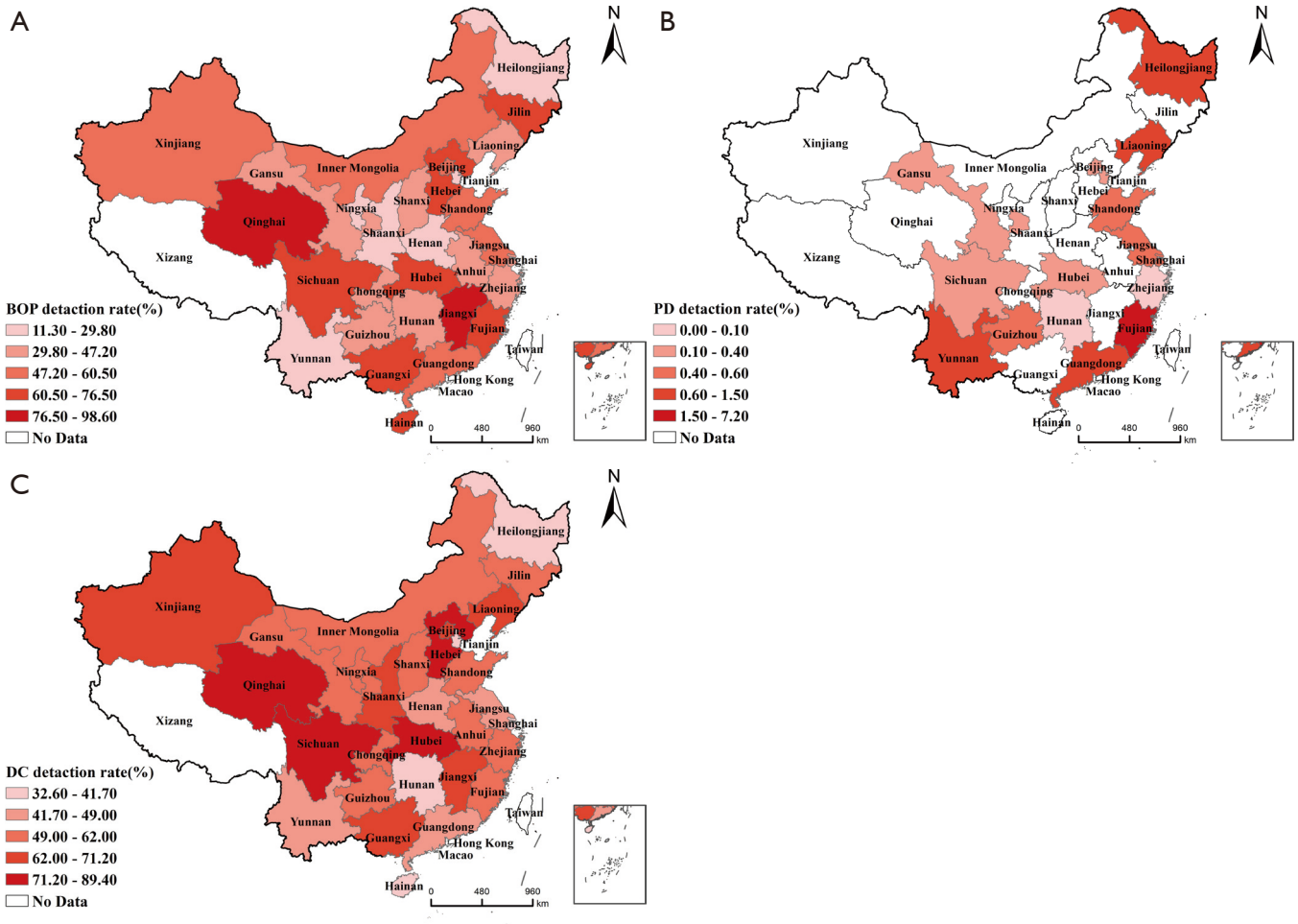

Figure 5 Regional distribution of detection rates of periodontal disease among adolescents in mainland China.

the three indexes were asymmetric (Figure S1). Beyond that, Begg's tests also suggest publication bias (P<0.001). A sensitivity analysis was conducted by eliminating each study to detect changes in conclusions of statistical analysis (53). After eliminating each study, the conclusions of statistical analysis are not influenced, which means the robustness of results.

Discussion

This study aims to present the epidemic trend of periodontal disease in adolescents in China. Periodontal disease is considered a common disease among the elderly. Further, the prevalence rate of gingivitis among the elderly in China is 57.9% (2). The results showed that the prevalence rate of gingivitis among adolescents estimated by BOP(+) was 48.8%, so the periodontal situation of adolescents should not be ignored, which was reported to be 20% in South Australia (54), 34.9% in Italy (55), and 14% in Japan (11). These differences in the results of gingivitis prevalence may be related to better oral hygiene and related consciousness in developed countries (56,57). In this review, only 13 studies reported the detection rate of PD ≥4 mm, the prevalence rate of gingivitis among adolescents estimated by PD ≥4 mm was 1%, an increasing trend is observed from 1983 to 2020. Therefore, a prompt periodontal examination of adolescents is essential.

In the adolescent population, oral epidemiological surveys usually focus on dental caries, and there are few reports on periodontitis. For instance, the national oral health surveys in the United States (58) and South Australia (54) reported only the prevalence of dental caries, DC, or gingival bleeding in adolescents, with no reference to periodontitis in adolescents. The detection rates of PD

≥4 mm at the population over 15 years old, for avoiding the false pockets formed during the eruption of permanent teeth, suggested by Petersen *et al.* (52). This is one reason there are fewer reports of periodontitis in adolescents. However, among the included studies, seven studies (25-31) examined the PD of participants under 15 years old, and four (25,26,28,30) reported positive results. PD examination is vital for young people under the age of 15. Hence, the improvement of the examination method is beneficial for the diagnosis of periodontitis and the identification of false periodontal pockets. Attempts can be made to examine the PD regularly when finding deep periodontal pockets. Jenkins and Papapanou (57) also suggested that preference was given to epidemiological publications of periodontitis in adolescents with radiographic marginal bone levels or proximal probing attachment loss, to avoid false periodontal pockets.

Three of the included studies reported aggressive periodontitis (25-27), which happens primarily in the young population and presents a rapid progression of inflammation. Since local irritants (DC and plaque) are rare with slight gum inflammation, aggressive periodontitis is easily overlooked at early stage (59). In 2017, European and American experts proposed to combine "chronic periodontitis" and "aggressive periodontitis" into "periodontitis" (60), removing the classification of aggressive periodontitis. Although the prevalence of aggressive periodontitis is not high, and the damage is severe. Rapid loss of periodontal tissues and even tooth loss are easily found during the development of the disease. Unfortunately, the disease progresses quickly and becomes rapidly serve with poor prognosis when young patients suffer pain and discomfort. It has a significant influence on chewing function, aesthetics. So, aggressive periodontitis emphasizes early detection, early diagnosis, prompt treatment, for avoiding irreversible damage to the periodontal tissue.

There were significant differences in the epidemic distribution of gingivitis among genders and the rural and urban population in China. A higher prevalence was observed in rural areas than urban. These phenomena may be associated with the unequal distribution of oral health services. In 2009, there were 286 dental hospitals in China. Only ten were built at the county level (61).

This may be attributed to the different oral hygiene habits of adolescents in rural and urban population, since good oral hygiene habits may contribute to the decline in the incidence of gingivitis (62). Studies (63,64) have reported that oral health practices and regular dental care habits were more frequent in urban areas than rural. Also, the estimated prevalence of gingivitis observed in boys (51.0%) was significantly higher than in girls (48.7%). Such discrepancies may be because of oral hygiene habits among boys and girls. Earlier studies (65,66) have reported girls were considerate of their oral health and had a lower prevalence of gingivitis.

High heterogeneity in a meta-analysis from epidemiologic surveys are inevitable (67,68). In this study, several factors might influence the heterogeneity: (I) the included studies had different sample sizes; (II) the sample populations had unique characteristics, including gender and area. Subgroup analysis for these unique characteristics, including gender and area, was conducted to explore the heterogeneity. After the subgroup analysis, the values of I^2 reduced to 0% and 27.1% for the detection rate of PD ≥4 mm, respectively; (III) bias in clinical examination also should be considered. For example, the diagnosis of PD was with the subjective judgment of the individual.

Some other limitations should also be considered in this study. First, studies that reported periodontal pockets status were insufficient, which may affect the accuracy of the result. Second, some studies only choose adolescents at a certain age, and others recruited adolescents in a broader age range. This difference may cause different sample sizes of the different age range. Third, The inspection methods of periodontitis were not standardized in all included studies, which was one of the main heterogeneities of this meta-analysis. To address this issue, a sensitivity analysis was conducted by eliminating each study to detect changes in conclusions of statistical analysis. After eliminating each study, the conclusions of statistical analysis are not influenced, which means the robustness of results. Finally, Publication bias in three indexes was observed, due to our selection criteria that only included peer-reviewed articles, but not other publication types such as "grey literature." The bias may also affect the estimates, even though we aimed to acquire all the relevant studies.

In conclusion, for adolescents, our results show a higher prevalence of gingivitis among the male and rural populations. Although the prevalence of periodontitis is 1%, it may lead to periodontal tissue loss rapidly and even the loss of a tooth for adolescents. Hence, more emphasis should be placed on the periodontal health of adolescents to prevent periodontal disease. Higher-quality epidemiological surveys with standard examination criteria are needed.

Acknowledgments

Funding: The National Natural Science Fund supported

this project (Grant No. 81700982), "Mechanism research on hypoxic upregulation of lncRNA-01126/HIF-1α/MAPK pathway in promoting periodontitis."

Footnote

Reporting Checklist: The authors have completed the PRISMA reporting checklist. Available at http://dx.doi.org/10.21037/apm-20-1919

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/apm-20-1919). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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(English Language Editor: J. Chapnick)

Cite this article as: Xiao L, Karapen K, Dong S, Yang H, Zhang X. Epidemiology of periodontal disease in adolescents in mainland China, 1983–2020: a systematic review and meta-analysis. Ann Palliat Med 2021;10(1):45-60. doi: 10.21037/apm-20-1919

Table S1 STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No.	Recommendation	Page No.	Relevant text from manuscript
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract		
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found		
Introduction				
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported		
Objectives	3	State specific objectives, including any prespecified hypotheses		
Methods				
Study design	4	Present key elements of study design early in the paper		
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection		
Participants	6	(a) Cohort study—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up Case-control study—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls Cross-sectional study—Give the eligibility criteria, and the sources and methods of selection of participants		
		(b) Cohort study—For matched studies, give matching criteria and number of exposed and unexposed Case-control study—For matched studies, give matching criteria and the number of controls per case		
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable		
Data sources/measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group		
Bias	9	Describe any efforts to address potential sources of bias		
Study size	10	Explain how the study size was arrived at		
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why		
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding		
		(b) Describe any methods used to examine subgroups and interactions		
		(c) Explain how missing data were addressed		
		(d) Cohort study—If applicable, explain how loss to follow-up was addressed Case-control study—If applicable, explain how matching of cases and controls was addressed Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy		
		(e) Describe any sensitivity analyses		
Results				
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed		
		(b) Give reasons for non-participation at each stage		
		(c) Consider use of a flow diagram		
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders		
		(b) Indicate number of participants with missing data for each variable of interest		
		(c) Cohort study—Summarise follow-up time (eg, average and total amount)		
Outcome data	15*	Cohort study—Report numbers of outcome events or summary measures over time		
		Case-control study—Report numbers in each exposure category, or summary measures of exposure		
		Cross-sectional study—Report numbers of outcome events or summary measures		
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included		
		(b) Report category boundaries when continuous variables were categorized		
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period		
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses		
Discussion				
Key results	18	Summarise key results with reference to study objectives		
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias		
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence		
Generalisability	21	Discuss the generalisability (external validity) of the study results		
Other information				
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based		

*, give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies. Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

http://dx.doi.org/10.21037/apm-20-1919

Table S2 Agreement among authors on titles and abstracts [kappa coefficients]

Author1	Author2		
	Exclusion	Inclusion	Total
Exclusion	2,530	41	2,571
Inclusion	33	268	301
Total	2,563	309	2,872

K1=0.864139.

Table S3 Agreement among authors on full-text analysis [kappa coefficients]

Author1	Author2		
	Exclusion	Inclusion	Total
Exclusion	725	7	732
Inclusion	5	26	31
Total	730	33	763

K1=0.804278.

http://dx.doi.org/10.21037/apm-20-1919

Table S4 Quality assessment of included 30 studies

Study	Title & abstract		Introduction		Methods													Results										Discussion				Other information	Number of Y
	1a	1b	2	3	4	5	6	7	8	9	10	11	12a	12b	12c	12d	12e	13a	13b	13c	14a	14b	15	16a	16b	16c	17	18	19	20	21	22	
Ding, 1983	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	28
Wang *et al.*, 1990	Y	N	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Y	Y	25
Wan *et al.*, 1994	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Y	Y	Y	27
Tan *et al.*, 1995	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	N	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	26
Li *et al.*, 1997	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y	27
Duan *et al.*, 2000	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	Y	Y	27
Zhang *et al.*, 2000	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y	N	N	Y	Y	Y	Y	Y	Y	N	Y	Y	N	Y	N	Y	Y	Y	25
Tian *et al.*, 2007	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	N	Y	Y	Y	25
Hu *et al.*, 2002	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y	N	Y	N	Y	Y	Y	26
Li *et al.*, 2002	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	N	N	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	N	Y	N	Y	Y	Y	25
Lei *et al.*, 2006	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y	26
Lin & Li., 2004	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	28
Wu *et al.*, 2006	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	N	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	28
Liao *et al.*, 2004	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	27
Jiang *et al.*, 2007	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	29
Wu *et al.*, 2007	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	N	N	Y	N	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	N	Y	Y	Y	25
Xie *et al.*, 2009	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	N	Y	Y	Y	27
Yang & Li, 2010	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	26
Cheng *et al.*, 2010	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Y	Y	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	27
Liu *et al.*, 2011	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	N	Y	N	Y	Y	Y	25
Bao *et al.*, 2013	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y	N	Y	Y	Y	26
Bi *et al.*, 2014	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	N	N	Y	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y	26
Liu *et al.*, 2014	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	N	Y	Y	Y	25
Chen *et al.*, 2017	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	N	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	N	Y	Y	Y	25
Yin *et al.*, 2017	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	N	N	Y	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	Y	26
NCOH, 1998	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	32
NCOH, 2009	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	32
NCOH, 2018	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	32
Lin *et al.*, 2018	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	27
Liu *et al.*, 2019	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	28

Y, yes; N, no; NCOH, National Committee for Oral Health.

http://dx.doi.org/10.21037/apm-20-1919

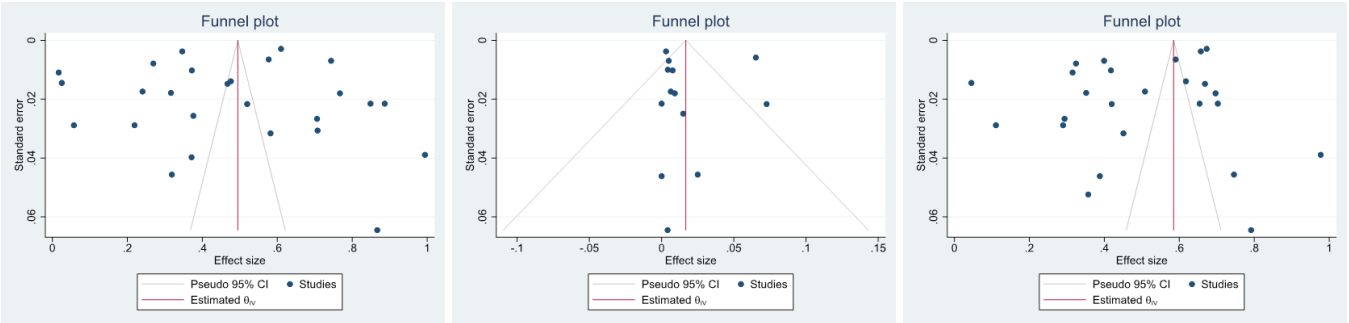

Figure S1 Funnel plots for studies.

http://dx.doi.org/10.21037/apm-20-1919