Analysis of epidemiological trends of and risk factors for tooth loss among 35- to 44-year-old adults in Guangdong, southern China, 1995-2015

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Abstract

Background

This study analyzed an epidemiological survey of oral health status among a representative population of adults aged 35–44 years in Guangdong Province from 1995 to 2015. The main purpose of this study was to describe the distribution and trends in tooth loss, derive related risk factors, provide theoretical evidence to support research on tooth loss in adults, help other cities explore comprehensive tooth loss intervention projects, and provide a relevant policy basis for health care planning decisions.

Methods

The data of 1408 participants of three cross-sectional, representative oral epidemiological surveys in Guangdong Province in 1995, 2005, and 2015 were analyzed. Basic demographic information, socioeconomic status, caries and periodontal statuses, personal lifestyle factors, and dental health care behaviors were analyzed by multivariate logistic regression to estimate their associations with tooth loss.

Results

This study found that the mean number of missing teeth (MT) and the prevalence of tooth loss (MT > 0) among adults aged 35–44 years in Guangdong Province did not change significantly in the first decade (1995–2005) but decreased significantly in the second decade (2005–2015) (0.942 and 40.8% in 1995, 0.989 and 42.9% in 2005, and 0.628 and 33.3% in 2015, respectively). The mean number of MT by tooth position was highest for the first molar, followed by the second molar, and both were larger in the mandible than in the maxilla. Education level, caries, and periodontal pocket (periodontal probing depth ≥ 4 mm) in 1995 and 2005 and sex, residence, caries, and periodontal pocket in 2015 were significantly associated with the prevalence of tooth loss.

Conclusions

Although tooth retention has improved in recent decades (1995–2005), measures to prevent tooth loss in adults, especially first molar loss, need to be continued in the future. Moreover, efforts to prevent tooth loss among women, those living in rural areas, and those suffering from caries and periodontal pocket need to be strengthened.

Background

Oral disease was one of the most common nonfatal health issues according to the Global Burden of Diseases hierarchy 2017 [1]. Tooth loss is one of the most prevalent and critical oral diseases worldwide [2]. The global prevalence and incidence of tooth loss have declined significantly in recent decades [3]. However, as of 2017, approximately 267 million people worldwide were suffering from complete edentulousness [4]. Tooth loss can have negative functional, aesthetic, and psychological consequences [5–7], reducing oral health-related quality of life [8]. It is also associated with anemia, cardiovascular disease, stroke, and end-stage renal disease [9–11]. The effects of tooth loss on other organs may result from risk factors associated with tooth loss leading to the release of inflammatory mediators. Tooth loss is therefore an essential indicator of oral and systemic health.

Several studies worldwide have monitored and analyzed tooth loss and found that many factors contribute to the occurrence of tooth loss, such as population background (education level, income, and ethnicity) [12–14], lifestyle habits (smoking and sweet consumption) [15, 16], and oral disease presence (caries and periodontal pocket) [17]. The distribution of tooth loss and its influencing factors vary between countries and regions and are dependent on economic development, cultural, educational, and other factors. In China, although there has been a significant improvement in the status of tooth loss among adults compared with that a decade ago, the rate of MT > 0 among adults aged 35–44 years was 32.3% in 2015 [18].

Three oral health surveys were conducted in Guangdong Province in 1995, 2005, and 2015 to investigate the status of tooth loss among adults aged 35–44 years. The rapid development of the social economy prompted many changes over these two decades. According to the Seventh National Census of China, the population aged 15–59 years in Guangdong Province increased by more than 10 million people compared to that in the Sixth National Census. In addition, the male-biased sex ratio, the proportion of the urban population and the proportion of people with nine years of education or more increased. The classic diet is shifting, as the traditional dietary patterns of many young Chinese individuals are being influenced by Westernized diets, resulting in increased sugar intake [19]. Moreover, dentistry spending among Chinese adults was low, and basic medical insurance for oral health has not changed significantly in recent years [20]. The abovementioned factors may impact the population's oral health in Guangdong Province. However, no studies on the risk factors influencing tooth loss among 35- to 44-year-olds in Guangdong Province have been conducted. It is not clear how the status of tooth loss and the factors influencing the prevalence of tooth loss in this population have changed over the past two decades. This study was therefore carried out to analyze this issue.

Cross-sectional studies can provide a good understanding of the prevalence of disease and its distribution characteristics at the time, which can provide clues for the development of preventive measures and for the study of the cause of the disease. Thus, the study analyzed data from three cross-sectional and representative oral epidemiological sample surveys conducted in 1995, 2005, and 2015, with the aim of summarizing and analyzing tooth loss among adults aged 35–44 years in Guangdong Province through dental indicators such as the prevalence of tooth loss and the number of missing teeth. Furthermore, assessing changes in tooth loss status and the factors influencing the prevalence of tooth loss over the twenty-year study period can predict the future trend of tooth loss, provide theoretical evidence to support research on tooth loss in adults, help other cities explore comprehensive tooth loss intervention projects and provide a relevant policy basis for health care planning decisions.

Methods

Source of data

Three epidemiological oral health surveys were conducted among adults aged 35–44 years in Guangdong Province in 1995, 2005, and 2015; the surveys were cross-sectional and representative. This study analyzed the data collected from the abovementioned surveys.

Participants

The inclusion criteria were as follows: 35–44 years of age, residents of Guangdong Province (who had lived there for at least six months prior to the survey month), no serious systemic diseases that would interfere with dental examination cooperation or questionnaire, and signed informed consent.

Exclusion criteria were age over 44 years or less than 35 years, residents of Guangdong for less than six months prior to the survey month, inability to cooperate with dental examinations or questionnaire, and lack of informed consent.

Sample design

This study used stratified, multistage, cluster, and random sampling techniques to obtain samples from a representative population in Guangdong Province, China. In 1995, 3 urban areas and 3 rural areas in Guangdong Province were randomly selected; 4 streets/towns were selected in urban or rural area, for a total of 8 study sample points. A total of 50 adults were sampled per point, for a total of 400 adults. In 2005, 3 urban areas and 3 rural areas in Guangdong Province were randomly selected; 3 streets/towns were selected in all area, for a total of 18 study sample points. A total of 40 adults were sampled per point, for a total of 720 adults. In 2015, 4 urban areas and 4 rural areas in Guangdong Province were randomly selected; 3 streets/towns were selected in all area, for a total of 24 study sample points. A total of 12 adults were sampled per point, for a total of 288 adults. Overall, 1408 adults were included in the final sample, and the ratios of males to females and urban areas to rural areas were both 1:1. (Fig. 1)

Dental examination desgin

Dental examinations were carried out by 3 examiners and recorded by 3 assistants for each survey year. All of the examiners were experienced dentists who had practiced clinical work for more than 3 years. Before the surveys, 3 examiners were provided training and initial calibration by a standard examiner. The kappa values of the three examiners to the standard examiner for caries examinations were > 0.8 and for periodontal examinations were > 0.6.

The standard examination equipment included an examination light, a dental mirror, and a community periodontal index (CPI) probe. All visible teeth except the third molars were checked in the following order: #17 to #27, then #37 through #47. The diagnostic criteria applied in this study referred to the World Health Organization (WHO) oral health survey basic methods (3rd, 4th, and 5th edition) and are as follows:

1. Crown caries/root caries: crown caries was defined as an obvious cavity, underenamel destruction, or a softened lesion at the crown that was detected on the base or wall. Root caries was defined as CPI probe detection of root cementum destruction or lesions with a soft or leathery feel.
2. Periodontal pocket: periodontal pocket was defined as periodontal probing depth of ≥ 4 mm.
3. Tooth loss status: missing teeth due to caries or other causes were defined as MT. (In this study, MT > 0 was defined as the prevalence of tooth loss, and the outcome variable was treated as binary variable in this study ("MT = 0" and "MT ≥ 1")).

Questionnaire design

The in-person, one-on-one questionnaire was conducted by trained interviewers. Standardized training was conducted before questionnaire administration, and consistency among interviewers after training was > 95%. The questionnaire answers for the three surveys were not the same. Thus, in this study, common variables for all three questionnaires were identified, and the final inclusion variables were grouped into four categories, as follows: (1) basic demographic information, including name, sex, and age; (2) socioeconomic status, including registered permanent residence type, education level, and annual household income; (3) personal lifestyle factors, including oral hygiene practices, sweets consumption, smoking, and alcohol consumption; and (4) dental health care behaviors, including the duration of the last dental visit, the reason for the last dental visit (within a year), and the payment mode of the dental visit (within a year).

Registered permanent residence type could be classified into two categories: urban area and rural area. Education level was divided into two categories by the number of years at school, with the cutoff being the median years per survey: low educational attainment (≤ 9 years, graduation from junior high school or less) and high educational attainment (> 9 years, more than graduation from junior high school). Annual household income was categorized into 3 levels by quartiles per survey: low income (< quartile 1), medium income (quartile 1 to quartile 3), and high income (> quartile 3). Tooth brushing was categorized by frequency as ≤ once per day or ≥ twice per day. Dental flossing was categorized by frequency as yes or no. Toothpaste was categorized into fluoride toothpaste or nonfluoride toothpaste. Sweets consumption, which included the consumption of sweet snacks and sweet beverages, was classified by frequency into three levels: rarely, sometimes (< twice per day), and often (≥ twice per day). Smoking and alcohol consumption were classified as yes or no for each. The duration of the last dental visit was categorized by frequency as < one year or ≥ one year. The reason for the last dental visit (within a year) was categorized as treatment, consultation, or prevention. Dental visit payment mode (within a year) was classified as entirely out of pocket and nonfully out of pocket.

Statistical analysis

Due to the different distribution of the total population among the regions, post hoc stratification was required to ensure the sample population was representative of that region's total population and to adjust for deviations in the sample and overall distribution of important indicators caused by sampling. This method assigns ex post stratified weights to each sample, with the sample distributions of indicators by weight consistent with the overall distribution. The ex post stratified weighted overall population was the resident population of each city in Guangdong Province in 2010, with information obtained from China's National Bureau of Statistics. Populations were stratified by sex (male and female) at each study sample point to improve the accuracy of the weights, and the stratification weights were calculated as follows: W = the proportion of males and females in the overall population of each city by sex/the proportion of males and females in the sample population of the corresponding measure. Data from this study were analyzed after being weighted and standardized using the above weightings.

Chi-square tests and Wilcoxon rank-sum tests were used to compare differences in the rates of MT > 0 and the mean numbers of MT among subgroups. The factors related to tooth loss were analyzed by multivariate logistic regression analysis. Odds ratios (ORs) and 95% confidence intervals (95% CIs) were estimated. The α level for statistical significance was set to 0.05. All statistical analyses were performed using IBM SPSS Statistics version 25.0.

Results

Tooth loss status

Mean number of MT and prevalence of tooth loss

The overall distributions of the mean number of MT ($H = 7.728$, $P = 0.021$) and the rate of MT > 0 ($\chi^2=7.889$, $P = 0.019$) from 1995 to 2015 showed statistically significant differences. The changes from 1995 to 2005 were nonsignificant ($P > 0.05$); the mean number of MT and the rate of MT > 0 slightly increased from 0.942 and 40.8% to 0.989 and 42.9%, respectively. Moreover, there was a significant decrease from 2005 to 2015 ($P < 0.05$) from 0.989 and 42.9% to 0.628 and 33.3%, respectively (Fig. 2).

The overall characteristics of the survey participants in 1995, 2005, and 2015 are displayed in Table 1. In 1995, the sex differences in the mean number of MT and the rate of MT > 0 were not statistically significant, but the mean number of MT was higher in rural than in urban areas ($Z=-2.351$, $P = 0.019$). In 2005, the regional differences in the mean number of MT and the rate of MT > 0 were not statistically significant, but the mean number of MT and the rate of MT > 0 were higher in females than in males ($Z=-2.582$, $P = 0.010$; $\chi^2=5.151$, $P = 0.023$). In 2015, the mean number of MT and the rate of MT > 0 were higher in rural than urban areas and in females than males, with statistically significant differences.

Table 1 Tooth loss status distribution of 35–44 years adults in Guangdong Province by residence areas, sex

Variable		N	MT>0			MT		
			n(%)	χ²	P-value	x̄ ± s	Z	P-value
Year of surveys :1995								
Total		400	163(40.7)			0.942±1.642		
Residence	Urban	200	74(37.0)	2.330	0.127	0.677±1.142	-2.351	0.019
	Rural	200	89(44.5)			1.208±1.991		
Sex	Male	203	74(36.5)	3.152	0.076	0.846±1.666	-1.733	0.083
	Female	197	89(45.2)			1.043±1.616		
Year of surveys :2005								
Total		720	309(42.9)			0.989±1.752		
Residence	Urban	361	152(42.1)	0.195	0.659	0.974±1.681	-0.394	0.694
	Rural	359	157(43.7)			1.004±1.823		
Sex	Male	359	139(38.7)	5.151	0.023	0.887±1.765	-2.582	0.010
	Female	361	170(47.1)			1.090±1.736		
Year of surveys :2015								
Total		288	96(33.3)			0.628±1.131		
Residence	Urban	144	38(26.4)	6.855	0.009	0.512±1.033	-2.265	0.023
	Rural	144	59(41.0)			0.743±1.213		
Sex	Male	158	42(26.6)	7.896	0.005	0.466±0.994	-3.018	0.003
	Female	130	55(42.3)			0.826±1.253		

Abbreviations: χ², chi-squared; Z, Wilcoxon rank-sum

Mean number of MT at different tooth positions

The mean numbers of MT at all tooth positions in the different survey years are shown in Fig. 3 A to C.

Among all the tooth positions, the first molar was the most common position in 1995, 2005, and 2015, followed by the second molar, and both were higher in the mandible than in the maxilla. In contrast, the mean numbers of MT in the anterior and first premolar positions were higher in the maxilla than in the mandible.

Univariate analysis

The result of the univariate analysis is shown in Table 2 and is discussed considering four categories.

Table 2 Univariate analysis of factors related to MT>0 among 35-44 years adults in Guangdong Province

Variables	N(%)	MT>0(%)	χ²	P-value
Year of surveys				
1995	400(28.4)	163(40.8)	7.889	0.019
2005	720(51.1)	309(42.9)		
2015	288(20.5)	96(33.3)		
Sex				
Male	720(51.1)	255(35.4)	15.027	0.001
Female	688(48.9)	313(45.6)		
Residence				
Urban	705(50.0)	264(37.4)	5.054	0.025
Rural	704(50.0)	305(43.3)		
Education level				
Low educational attainment	800(56.8)	363(45.4)	19.508	0.001
High educational attainment	608(43.2)	205(33.7)		
Annual household income				
Low income	457(32.7)	196(42.9)	1.811	0.404
Medium income	687(49.2)	270(39.3)		
High income	253(18.1)	98(38.7)		
Caries				
No	552(39.2)	129(23.4)	108.188	0.001
Yes	856(60.8)	439(51.3)		
Periodontal pocket				
No	981(69.7)	369(37.6)	10.215	0.001
Yes	427(30.3)	199(46.7)		
Tooth brushing				
≤once per day	656(46.6)	273(41.6)	0.699	0.403
≥twice per day	752(53.4)	296(39.4)		
Dental flossing				
No	1375(97.8)	555(40.3)	0.033	0.855
Yes	31(2.2)	12(38.7)		
Toothpaste				
Nonfluoride toothpaste	744(53.2)	301(40.5)	<0.001	1.000
Fluoride toothpaste	656(46.8)	265(40.4)		
Sweet consumption				

Rarely	221(16.9)	78(35.3)	2.723	0.256
Sometimes	953(72.8)	392(41.1)		
Often	136(10.3)	57(41.9)		
Smoking consumption				
No	943(67.0)	388(41.1)	0.613	0.434
Yes	465(33.0)	181(38.9)		
Alcohol consumption				
No	801(57.0)	336(41.9)	1.961	0.161
Yes	604(43.0)	231(38.2)		
Duration of the last dental visit				
<one year	269(29.7)	146(54.3)	1.189	0.276
≥one year	638(70.3)	321(50.3)		
The reason of the last dental visit(within a year)				
Treatment	249(93.1)	137(55.0)	3.004	
Consultation	12(4.5)	4(33.3)		0.223
Prevention	6(2.4)	5(71.4)		
The payment mode of the dental visit(within a year)				
Nonfully out of pocket	56(20. 8)	27(48.2)	1.120	0.290
Entirely out of pocket	212(79.2)	119(56.1)		

Abbreviations: χ^2, chi-squared.

Socioeconomic status

A total of 45.4% of adults with low educational attainment suffered from tooth loss; this proportion was 11.7% higher than that in those with high educational attainment (χ^2=19.508, P<0.001). The sample distribution of annual household income was 32.7% for low income, 49.2% for medium income, and 18.1% for high income. The prevalence of tooth loss decreased with increasing income level, but the difference was not statistically significant.

Caries and periodontal status

In total, 60.8% of adults suffered from caries, and 30.3% suffered from periodontal pocket. The prevalence of tooth loss was higher in those with caries than in those without (χ^2=108.188, P<0.001) and in those with periodontal pocket than in those without (χ^2=10.215, P =0.001).

Personal lifestyle factors

In total, 53.4% of adults brushed their teeth ≥twice per day, 46.8% used fluoride toothpaste, and only 2.2% flossed. The above results suggest that the rates of tooth brushing and the use of fluoride toothpaste are acceptable, but the practice of dental flossing needs to be popularized. The prevalence of tooth loss was lower among those who brushed ≥twice per day, used fluoride toothpaste and flossed than among those who brushed ≤once per day, used nonfluoride toothpaste, and did not floss. Those who frequently consumed sweets had a higher prevalence of tooth loss than those who rarely or sometimes consumed sweets. The prevalence of tooth loss was 2.2% lower among smokers than nonsmokers and 3.7% lower among alcohol drinkers than among nondrinkers. None of these differences were statistically significant.

Dental health care behaviors

Most adults had not visited the dentist within a year since their last visit, with only 29.7% reporting a dental visit within the past year. Among those who had visited the dentist within a year, 93.1% visited to seed treatment, while only 6.9% visited for consultation or prevention purposes. Furthermore, 79.2% of adults had to pay for the cost of the dental visit out of pocket. None of these differences were statistically significant.

Multifactor analysis

Variables with a P value<0.05 in the univariate analysis were included in the multivariate logistic regression models.

The multivariate logistic regression analysis showed that the risk of tooth loss was higher in 2005 than in 2015. Female sex and the presence of caries or periodontal pocket were risk factors for tooth loss. High educational attainment was a protective factor against tooth loss (Table 3).

After stratification by survey year, the logistic regression subgroup analyses showed that the presence of caries or periodontal pocket was a common risk factor in each subgroup, high educational attainment was a common protective factor in each subgroup in 1995 and 2005, and female sex and rural residence were risk factors in 2015. (Table 4)

Table 3 Multivariate logistic regression analysis of factors with MT>0 among 35-44 years adults in Guangdong Province

Variables	OR	95%CI	P-value
Year of surveys			
2015[a]	-	-	-
1995	1.361	0.976~1.900	0.070
2005	1.663	1.226~2.255	0.001
Sex			
Male [a]	-	-	-
Female	1.263	1.003~1.590	0.047
Residence			
Urban [a]	-	-	-
Rural	1.091	0.858~1.385	0.475
Education level			
Low educational attainment [a]	-	-	-
High educational attainment	0.700	0.548~0.895	0.004
Caries			
No [a]	-	-	-
Yes	3.413	2.668~4.365	0.001
Periodontal pocket			
No [a]	-	-	-
Yes	1.645	1.284~2.107	0.001

Notes: [a] Reference category. **Abbreviations:** OR, odds ratio; CI, confidence interval.

Table 4 Multivariate logistic regression analysis of factors with MT>0 among 35-44 years adults in Guangdong Province stratified by the year of surveys

Variables	1995			2005			2015		
	OR	95%CI	P-value	OR	95%CI	P-value	OR	95%CI	P-value
Sex									
Male [a]	-	-	-	-	-	-	-	-	-
Female	1.154	0.722~1.846	0.549	1.135	0.825~1.562	0.435	2.050	1.216~3.456	0.007
Residence									
Urban [a]	-	-	-	-	-	-	-	-	-
Rural	1.094	0.667~1.794	0.722	0.874	0.635~1.204	0.410	2.424	1.333~4.408	0.004
Education level									
Low educational attainment [a]	-	-	-	-	-	-	-	-	-
High educational attainment	0.458	0.275~0.761	0.003	0.673	0.483~0.938	0.019	1.438	0.794~2.606	0.231
Caries									
No [a]	-	-	-	-	-	-	-	-	-
Yes	13.514	7.017~26.023	0.001	2.715	1.963~3.756	0.001	2.010	1.155~3.496	0.013
Periodontal pocket									
No [a]	-	-	-	-	-	-	-	-	-
Yes	1.955	1.153~3.314	0.013	1.538	1.089~2.172	0.015	1.787	1.054~3.030	0.031

Notes: [a] Reference category. **Abbreviations:** OR, odds ratio; CI, confidence interval.

Discussion

A longitudinal study design can accurately observe the changes in trends and factors influencing tooth loss in the same sample and allows predictions, but it is a costly and time-consuming process. Moreover, there is a risk of loss to follow-up. Accordingly, this study analyzed data from three cross-sectional and representative oral epidemiological sample surveys. Ex post stratified weights and multivariate logistic regression analysis were used to minimize cohort effects. The main finding of the study was that the following factors influenced the prevalence of tooth loss among survey years: educational attainment, caries presence, and periodontal dpocket presence in 1995; educational attainment, caries presence, and periodontal pocket presence in 2005; and sex, residence, caries presence, and periodontal pocket presence in 2015. Each were significantly associated with the prevalence of tooth loss in that year. This study identified possible factors associated with tooth loss, provides a scientific basis for cross-sectional comparisons in other regions, and provides the evidence for the study of tooth loss in adults and the development of interventions in health care planning.

In this study, the mean number of MT and the prevalence of tooth loss were 0.942 and 40.8% in 1995 and 0.989 and 42.9% in 2005, respectively, with nonsignificant differences. However, the mean MT and the prevalence of MT>0 significantly decreased to 0.628 and 33.3%, respectively, from 2005 to 2015. The decline in the prevalence of tooth loss between 2005 and 2015 may be due to the increased investment in health services and the effectiveness of oral prevention strategies in China. The mean number of MT in 2015 was 2.3, and the prevalence of MT>0 was 75.5% in adults aged 35-44 in China [18]. In the UK, the number of remaining teeth in adults increased from 21.9 in 1968 to 25.7 in 2009 [21]. In Germany, the prevalence of MT>0 decreased from 76.6% in 1997 to 58.8% in 2005 and to 56.8% in 2014 [22]. In addition, the mean number of MT in Brazil decreased from 13.5 in 2002-2003 to 7.4 in 2010 [23]. The studies summarized above show that the status of tooth loss among adults in Guangdong Province is relatively better than those in China overall and abroad and that there is a trend toward improvement. However, this may also be related to the fact that residual roots and crowns were not considered missing teeth at the time of the surveys utilized in this study. This may lead to the conclusion that the risk factors for tooth loss among adults are not constant, but are always changing over time.

The mean number of MT among all tooth positions in the three surveys was highest for the first molar and higher in the mandible than in the maxilla. This result is similar to domestic and international findings that emphasize the larger number of missing teeth at the first molar position [18,24]. The first molar is the first permanent tooth to erupt in the mouth. However, many people are unaware that it is irreplaceable, and they do not take adequate protective measures, such as the application of pit and fissure sealant, resulting in the loss of the first molar. In Guangdong Province, the free first molar pit and fissure sealant program has been implemented for nearly ten years and has achieved specific results in controlling caries in children. In the future, an epidemiological survey of 35- to 44-year-old adults can be conducted to compare whether there has been any significant decrease in the mean number of MT at the first molar position.

Differences in the prevalence of tooth loss by sex and residence were not statistically significant between 1995 and 2005. However, the risk of tooth loss was 2.050 times higher in females than in males and 2.424 times higher in rural areas than in urban areas in 2015, with similar results reported in other studies [18,25,26]. There were sex differences between two studies conducted in Iran and Vietnam [27,28], and there were residency differences in a study in the Netherlands [29], whose results are contrary to our study. The differences in the sex and residency results may be related to different countries' cultures and economic development levels. According to data from the Seventh National Census of China, the proportion of males in Guangdong Province is increasing, the proportion of the rural population is decreasing annually, and sex and residency differences have increased. It is unclear why the differences between sexes and residence areas occurred in 2015, and this topic needs further research.

The risks of tooth loss in 1995 and 2005 were 0.458 and 0.673 times lower, respectively, in adults with high educational attainment than in those with low educational attainment. In contrast, the difference in the prevalence of MT>0 between education levels in 2015 was not statistically significant. The results in 1995 and 2005 suggest that higher educational attainment is beneficial in preventing tooth loss, consistent with the findings of other national studies [22,30,31]. For the results in 2015, this study inferred that the main reason was that the increase in education level eliminated its effect on tooth loss. There are two reasons for drawing this inference. First, the distribution of the number of years of education in this study showed that the proportion of those with > 9 years of education was less than the proportion of those with ≤ 9 years of education in 1995 and 2005, but the two categories contained the same proportion in 2015. The abovementioned distribution pattern may be explained by the nine-year compulsory education policy, which has been implemented in China since 1986, suggesting that the average education level increased significantly over the two-decade study period, affecting the difference in the prevalence of tooth loss. Second, Zhuhai, Guangdong Province, has been progressively implementing a twelve-year compulsory education policy since 2007. With the progression of the "universal twelve-year compulsory education system", it is believed that the education levels of 35- to 44-year-old adults in Guangdong Province will gradually increase, which may have a positive impact on the situation of tooth loss.

Caries and periodontal disease are, along with tooth loss, the most prevalent and vital oral diseases worldwide [2]. They are also the leading cause of tooth loss [2]. The presence of caries and periodontal pocket were common risk factors in all three surveys. The risks of tooth loss among those with caries in the three surveys were 13.514 times, 2.715 times, and 2.010 times higher than those among people without caries, with caries rates of 67.7%, 57.0%, and 60.7%, respectively.

The caries rate showed a decreasing trend, suggesting that caries prevention strategies were effective. However, the caries rate in 2015 was higher than that in 2005, suggesting that the impact of caries on tooth loss cannot be neglected, and prevention and treatment measures for caries should be strengthened. The risks of tooth loss among those with periodontal pocket were 1.955, 1.538, and 1.787 times higher than those among people without periodontal pocket in the three surveys. The periodontal pocket rates were 26.7%, 27.4% and 42.4%, respectively, with a significant increase in 2015. A previous review emphasized the negative role of root caries in the long-term preservation of teeth in patients with periodontal disease, and another study analyzed the risk of root caries in patients with periodontitis [33,34]. The results indicate an interactive effect between root caries and periodontitis. However, the relationship between crown caries and periodontal disease is still not clear and has been reported to be positive, negative, and unrelated [35-38]. In a recent article from China on the relationship between caries and periodontal disease, it was stated that among people aged 35-44 years, periodontitis had a significant association with mixed or root caries [39]. Therefore, the interaction between caries and periodontal disease needs to be recognized to prevent the adverse effect of tooth loss.

This study has several limitations. First, this study used data from three cross-sectional rather than continuous prospective data; thus, it cannot accurately predict the status of tooth loss in the next decade. Second, given the deviations in the samples and overall distributions of important indicators caused by the sampling method, this study assigned ex post stratified weights to each sample. Additionally, it explored the potential causal effects of confounding factors in each survey year. Nevertheless, there may still be bias in the results due to differences associated with time periods and economic development levels. Finally, the three surveys included different dental examination items and questionnaire contents, resulting in a reduction in the number of common variables and preventing comprehensive analysis of the prevalence of tooth loss from all perspectives.

Conclusions

In summary, the epidemiological status of tooth loss among adults aged 35-44 years in Guangdong Province in 2015 significantly improved compared with those in 1995 and 2005. The mean number of MT at the first molar position was high in all three surveys, and additional precautions must be taken. Additional preventive measures should target mainly females, adults living in rural areas, and those suffering from caries and periodontal pocket.

List Of Abbreviations

1. MT, missing teeth;
2. CPI, community periodontal index;
3. WHO, World Health Organization;
4. CI(s), confidence interval(s);
5. OR(s), odds ratio(s).

Declarations

Ethical Approval and Consent to Participate

The Oral Health Survey scheme was approved by the Stomatological Ethics Committee of the Chinese Stomatological Association (Permit Number: 2014-003). This study was conducted in accordance with the Declaration of Helsinki. All of the adults signed informed consent documents before the beginning of the study.

Consent for publication

Not applicable.

Availability of data and materials

The data that support the findings of this study are available on request from the corresponding author [Fan W]. The data are not publicly available due to them containing information that could compromise research participant privacy.

Competing interests

The authors declares that they have no competing interests.

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Authors' contributions

All authors made a significant contributions to the work reported. LXJ has contributed to conception, design, execution, acquisition of data, and drafted the manuscript;JBL has contributed to project administration and design; ZJY has contributed to data curation, visualization and interpretation of statistic results; XYH and BCL have contributed to investigation; XZ has contributed to methodology; YH has contributed to formal analysis; LMW has contributed to validation; SHH has contributed to review, editing, supervision, funding acquisition; WHF have contributed to review, editing, supervision and conceptualization. All authors read and approved the final manuscript.

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Figures

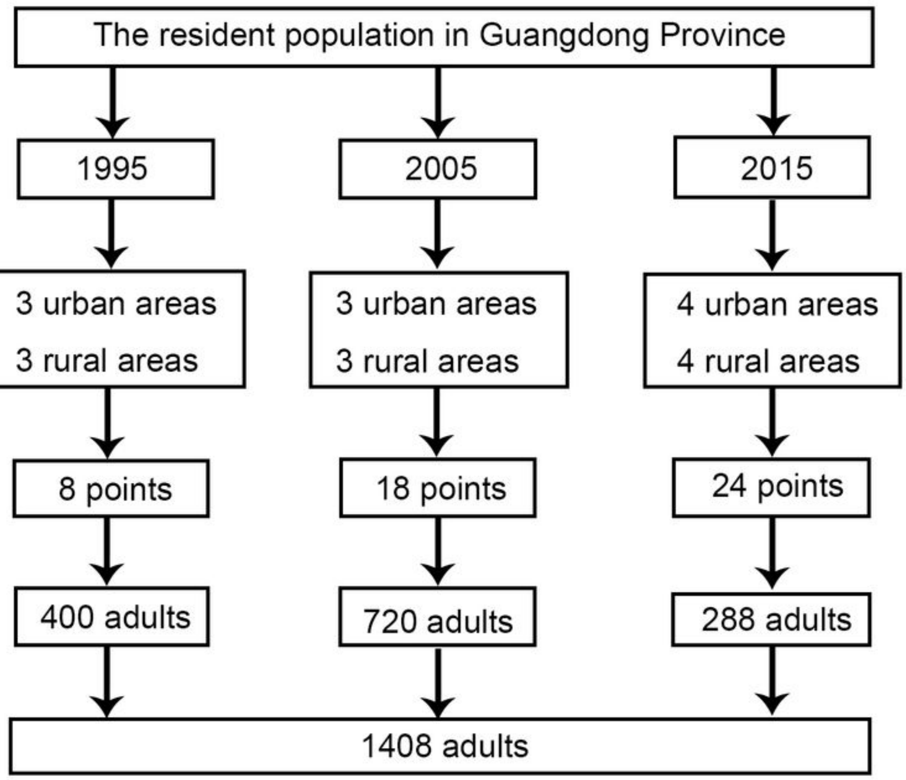

Figure 1

The sampling process.

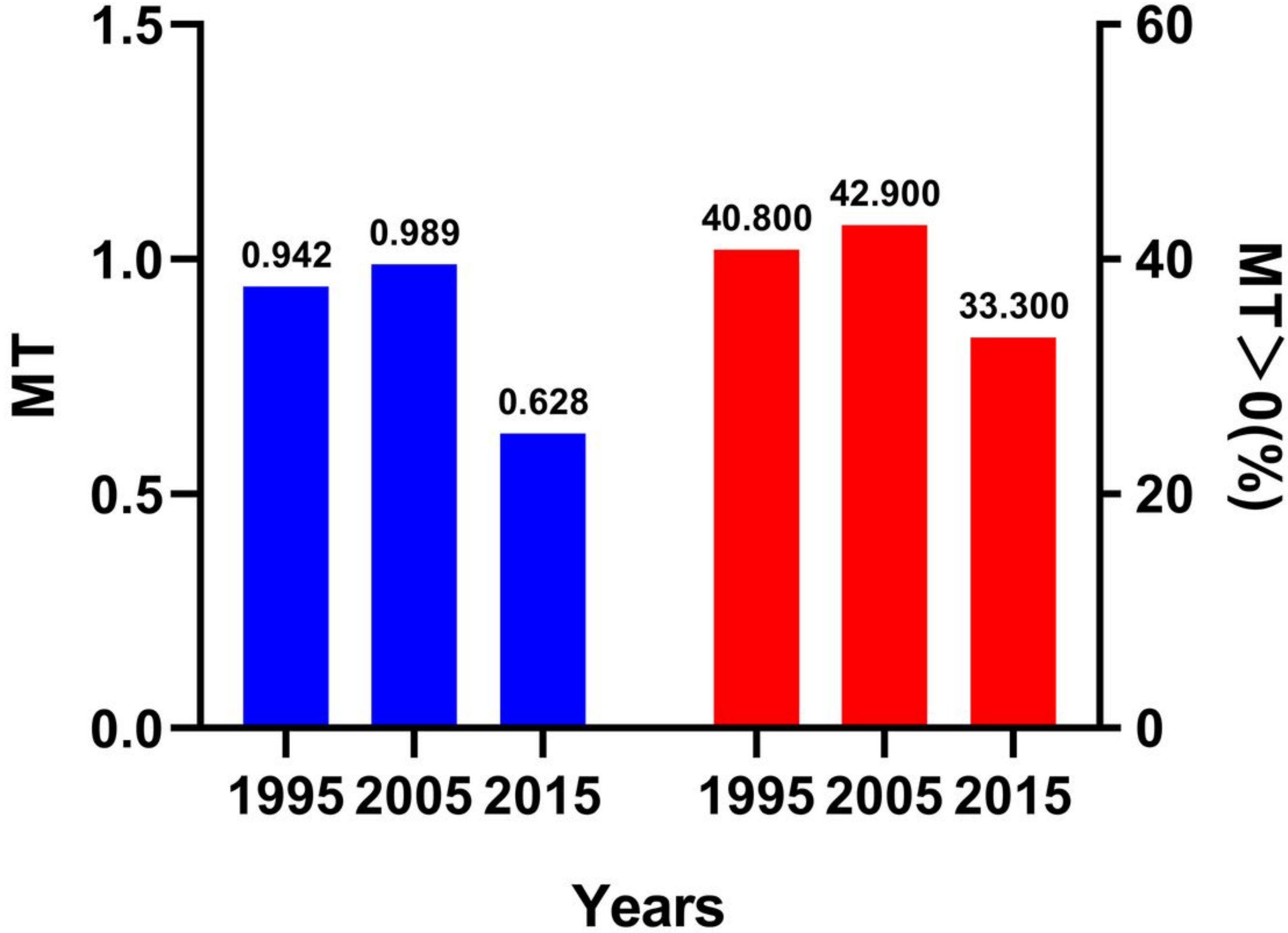

Figure 2

The mean number of MT and prevalence of tooth loss(MT>0) in different years of surveys.

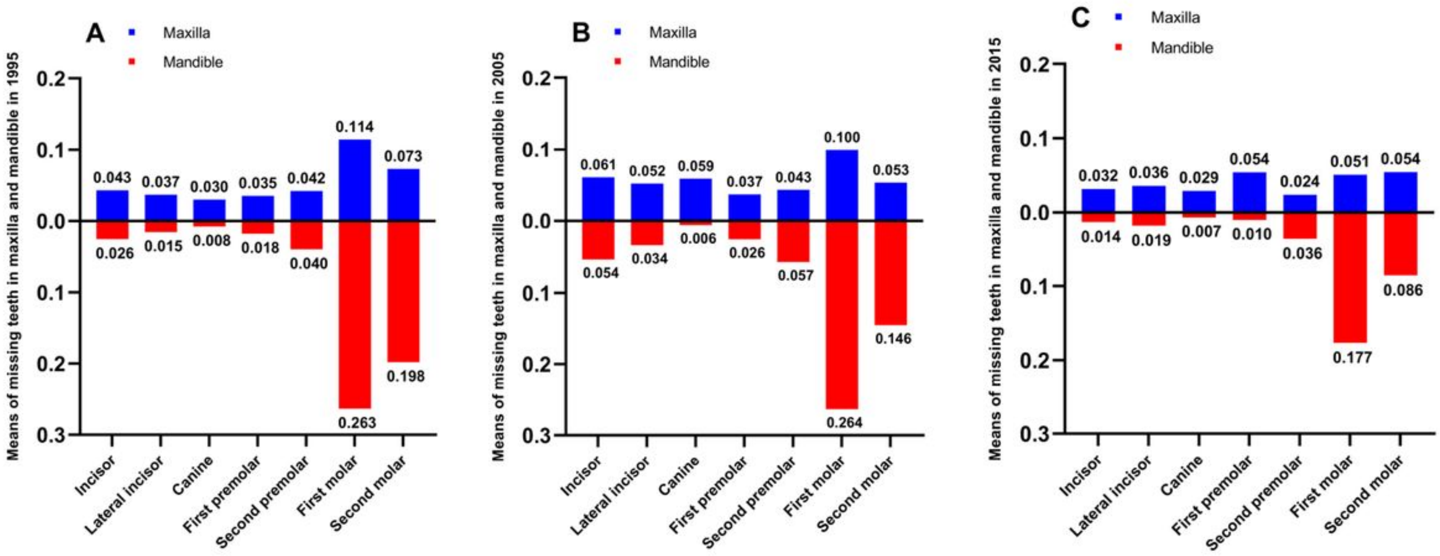

Figure 3

(A) The mean number of MT in maxilla and mandible in 1995 (B) The mean number of MT in maxilla and mandible in 2005 (C) The mean number of MT in maxilla and mandible in 2015.