Relationship between Chewing Sugar-free Gum and Dental Caries Status in China

Chun Zi ZHANG[1#], Shuo DU[1#], Wen Hui WANG[1], Jian LIU[1], Chao YUAN[1], Yi Zhen YU[1], Shan Shan ZHANG[1], Yan SI[1]

Objective: *To investigate the relationship between chewing sugar-free gum (SFG) and dental caries status in China.*

Methods: *A total of 860 teenagers (aged 12 to 15 years) and 490 adults (aged ≥ 18 years) were recruited using a multistage stratified cluster method from economically developed areas (Beijing, Guangdong) and less economically developed areas (Hubei, Xinjiang). Each participant completed a questionnaire including oral health-related knowledge of SFG and chewing habits of SFG and agreed to undertake a clinical assessment. Potential factors associated with chewing conditions were analysed through a chi-square statistical test. A negative binominal regression analysis was performed to quantify the relationship between dental caries and consumption of SFG.*

Results: *The overall percentage of the survey population who consumed SFG was 43.4%, and SFG-related knowledge and awareness was only 19.4%. For decayed, missing and filled permanent teeth (DMFT), the mean value was 1.63 ± 2.41 and 2.29 ± 3.65 in the chewing group and non-chewing group, respectively. According to the negative binominal regression analysis, the caries status in the SFG chewing group was better than in the non-chewing group (adjusted prevalence rate ratio [PRR] 0.73; 95% confidence interval [CI] 0.62–0.87).*

Conclusion: *The chewing condition and oral health-related knowledge and awareness of SFG is low. Chewing SFG is related to a better dental caries status, so regular consumption of SFG should be recommended when promoting oral health.*

Key words: *caries prevention, China, sugar-free gum*

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Dental caries is a common chronic bacterial infectious disease that has a severe effect on both oral and general health in humans[1,2]. According to reports from the World Health Organisation (WHO), oral disease has become one of the important contributing factors compromising quality of life[3]. The data on the global burden of disease from the Lancet showed that the prevalence of permanent dental caries ranked first among 328 main diseases worldwide[2]. The 4th National Oral Health Survey (NOHS) in China showed that the prevalence of dental caries was 41.9% and the mean value for decayed, missing and filled permanent teeth (DMFT) was 1.04 in the permanent dentition among individuals aged 12 to 15 years, and in individuals aged 35 to 44 years, the prevalence was 89.0% and the mean DMFT value was 4.54 in the permanent dentition[4]. There is still a relatively high prevalence of dental caries in teenagers and adults in China; thus, suitable strategies for caries prevention are urgently needed.

A number of studies have observed that chewing sugar-free gum (SFG) has an inhibitory effect on dental caries by stimulating the secretion of saliva, mechanically removing plaque and acting as an agent for antibac-

1 Department of Preventive Dentistry, Peking University School and Hospital of Stomatology, National Engineering Laboratory for Digital and Material Technology of Stomatology, Beijing Key Laboratory of Digital Stomatology, Beijing, P.R. China.

# These authors contributed equally to this work.

Corresponding authors: Dr Shan Shan ZHANG and Dr Yan SI, Department of Preventive Dentistry, Peking University School and Hospital of Stomatology, #22 Zhongguancun South Avenue, Haidian District, Beijing 100081, P.R. China. Tel: 86-10-82195634; Fax: 86-10-62173404. Email: leahzhang@126.com; siyanyy@163.com

terial ingredients[5-7]. There is evidence of a causal relationship between chewing SFG and caries reduction[8,9]. Reinhard et al[10] conducted a survey on chewing SFG use and the annual SFG consumption in China ranked the fourth lowest in 25 industrialised countries, far behind that in Switzerland, Sweden, the United States and other Western countries; however, there is limited information about SFG chewing habits in China. As such, the aim of the present study was to investigate the chewing condition of SFG in China and explore the relationship between chewing SFG and dental caries through a cross-sectional survey.

Materials and methods

The study was revised and approved by the Peking University School of Stomatology Institutional Review Board (no. PKUSSIRB-201942018).

Study design and sample selection

Eastern provinces (Beijing, Guangdong) of economically developed areas and the central (Hubei) and western province (Xinjiang) of less economically developed areas were included. A probability proportional to size (PPS) design was used to select one urban area and one rural area from each province at random after division of the urban and rural areas in each province. The PPS method was used to select one middle school and one neighbourhood community from an urban district or a village community in a rural district. Individuals aged 12 to 15 years were invited to participate in the survey and adults (aged ≥ 18 years) were recruited consecutively from neighbourhood or village communities using cluster sampling. The inclusion criteria were as follows:

- aged 12 to 15 years or 18 years and over;
- with at least one fully erupted permanent molar;
- in good general health.

Individuals with serious systemic diseases, enamel hypoplasia, fluorosis and tetracycline teeth, occlusal dysfunction, such as bruxism at night, tooth clenching, a history of related allergies, incomplete fractured teeth or dens evaginatus were excluded. The sample size was calculated using the formula ($n = (\mu^2(\alpha/2)\pi(1 - \pi)/\sigma^2)$ based on the prevalence of dental caries reported by the results of the 4th NOHS in China[4]. Allowable error was controlled at the level of 0.1. Considering the anticipated response rate of 90%, a total of 860 young people (aged 12 to 15 years) took part in the survey with their and their legal guardians' consent, and 490 adults (aged ≥ 18 years) signed the consent form prior to participating.

Data collection

According to the criteria of the 4th NOHS[11], all the subjects received an oral health examination through visual examination combined with probing under artificial light using plane mouth mirrors and a Community Periodontal Index (CPI) probe. Caries status was recorded in accordance with the WHO criteria[12]. In each province, three trained licensed dental practitioners who had been calibrated by the training of the 4th NOHS under WHO guidelines performed the examination. The kappa values were 0.80~0.96.

A structured questionnaire covering areas including socioeconomic and demographic information, knowledge of SFG, SFG chewing habits, knowledge about and attitude towards oral health, and oral health promoting behaviours were recorded. For the 12- to 15-year-olds, schoolteachers and interviewers co-organised and illustrated the content of the questionnaire, then the participants answered all the questions by themselves in the classroom, and for the adults, the structured questionnaires were recorded by trained interviewers, using a face-to-face interview method.

Data analysis

The caries status related to demographic characteristics and SFG chewing habits were displayed by descriptive analysis. Factors that may be related to the chewing condition were analysed using a chi-square statistical test. Furthermore, the mean DMFT value was compared across all categories of involved factors using non-parameter tests (Mann-Whiney test for two-categorised variables and Kruskal-Wallis test for factors with three or more categories) as the DMFT value was not normally distributed. Detailed information regarding the grading standard of each variable is presented in a supplemental table (provided on request).

For multivariable analysis of the DMFT value, due to the overdispersion (variance exceeds the mean) and the result of the Vuong test[13], a negative binominal regression model was preferred to estimate the prevalence rate ratio (PRR). Two models were constructed to measure the crude and adjusted effects of SFG consumption on DMFT values. In model 1, SFG consumption was introduced as the only independent variable, then factors related to the mean DMFT with statistical significance at the 0.05 level were added in model 2.

All statistical analyses were performed using SPSS Statistics v.25.0 (IBM, Armonk, NY, USA) and STATA SE 15.0 (Stata, College Station, TX, USA). The *P* values reported were two-tailed, and statistical significance was set at 0.05.

Table 1 Dental caries status related to subjects' demographic characteristics by age group.

Variable		Teenager		Adult		Overall	
		Number of subjects (%)	Mean DMFT value	Number of subjects (%)	Mean DMFT value	Number of subjects (%)	Mean DMFT value
Total		860 (100)	1.14	490 (100)	3.50	1350 (100)	2.00
Sex	Male	417 (48.6)	0.93	196 (40)	3.04	613 (45.5)	1.60
	Female	441 (51.4)	1.35	294 (60)	3.81	735 (54.5)	2.33
Region	Less developed area	426 (49.5)	1.04	246 (50.2)	3.99	672 (49.8)	2.12
	Developed area	434 (50.5)	1.24	244 (49.8)	3.01	678 (50.2)	1.88
Nationality	Han	711 (83.1)	1.09	412 (84.3)	3.10	1123 (83.5)	1.83
	Minorities	145 (16.9)	1.43	77 (15.7)	5.66	222 (16.5)	2.90
Residential area	Urban	536 (64.3)	1.11	326 (67.5)	3.85	862 (65.5)	2.15
	Rural	298 (35.7)	1.20	157 (32.5)	2.69	455 (34.5)	1.72

Note that some values in the cells do not add up to the total number of participants due to missing values including sex, nationality and residential area, but the percentages for each variable were calculated using the actual number without missing values.

Table 2 SFG chewing habits and knowledge of SFG in different age groups in China.

Variable		Teenagers, n (%)	Adults, n (%)	Overall, n (%)
Chewing frequency	Hardly/never	433 (50.8)	325 (66.9)	758 (56.6)
	1–3 times a month	197 (23.1)	83 (17.1)	280 (20.9)
	Once a week	73 (8.6)	31 (6.4)	104 (7.8)
	2–6 times a week	74 (8.7)	23 (4.7)	97 (7.2)
	Once a day	41 (4.8)	18 (3.7)	59 (4.4)
	At least twice a day	35 (4.1)	6 (1.2)	41 (3.1)
Knowledge of SFG	Not acquired	693 (81.1)	384 (79.7)	1077 (80.6)
	Acquired	162 (18.9)	98 (20.3)	260 (19.4)

Results

A total of 860 12- to 15-year-olds and 490 adults were included in the study. An overview of dental caries status related to demographic characteristics is provided in Table 1.

Table 2 illustrates that a total of 43.4% of subjects reported that they chewed SFG at varying frequencies and the SFG-related knowledge and awareness was only 19.4%. Only 7.5% chewed SFG on a daily basis. The mean DMFT values were 1.63 ± 2.41 and 2.29 ± 3.65 in the chewing group and non-chewing groups, respectively (Table 3).

Table 4 shows possible influencing factors for the SFG chewing habits in the different age groups. The chewing condition was apparently associated with sex, region, nationality, oral health-related knowledge of SFG use of dental floss, sugar consumption habits and intention of the most recent dental visit. The proportion of individuals who chewed SFG was higher in teenagers whose parents had a high level of education. In adults, those with a high level of education were more likely to chew SFG.

Table 5 explores the potential correlative factors for the mean DMFT value in different age groups. The results exhibited that five variables were significantly associated with the DMFT value: sex, nationality, consumption of SFG, history of dental visits in the past 12 months and the intention of the most recent visit. Adults from economically developed areas reported a lower DMFT value.

Table 6 presents a multivariate negative binomial regression analysis of the mean DMFT value. In model 1, the mean DMFT value in the chewing group was obviously lower than that of the non-chewing group, with a crude PRR of 0.71 (95% confidence interval [CI] 0.61–0.84). After factors associated with the mean DMFT value were introduced into model 2, the PRR was adjusted to 0.73 (95% CI 0.62–0.87). People who chewed SFG (PRR 0.73, 95% CI 0.62–0.87), were male (PRR 0.71, 95% CI 0.60–0.85), of Han nationality (PRR 0.65, 95% CI 0.51–0.83) and not having had a dental visit in the past 12 month (PRR 0.82, 95% CI 0.70–0.98) were less likely to have caries.

Table 3 Oral health status of subjects by SFG chewing habits.

Variable	Chewing group			Non-chewing group		
	Teenagers	Adults	Overall	Teenagers	Adults	Overall
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
DT	0.98 ± 1.46	1.29 ± 2.07	1.07 ± 1.65	0.82 ± 1.55	1.74 ± 2.28	1.22 ± 1.95
MT	0.00 ± 0.05	0.30 ± 1.06	0.09 ± 0.57	0.01 ± 0.16	0.76 ± 2.67	0.33 ± 1.79
FT	0.21 ± 0.79	1.17 ± 2.24	0.48 ± 1.42	0.27 ± 0.90	1.37 ± 2.81	0.74 ± 2.04
DMFT value	1.20 ± 1.72	2.77 ± 3.38	1.63 ± 2.41	1.10 ± 1.79	3.87 ± 4.74	2.29 ± 3.65

DT, decayed teeth; FT, filled teeth; MT, missing teeth.

Table 4 Possible influencing factors for the SFG chewing condition in different age groups.

Variable		*P* value		
		Teenagers	Adults	Overall
Social demographics	Sex (male/female)	0.295	0.004	0.003
	Region (less developed area/developed area)	0.037	0.058	0.006
	Nationality (Han/others)	0.015	0.520	0.015
	Parental education level (low/medium/high)	0.003	NA	NA
	Educational level (low/medium/high)	NA	0.017	NA
Knowledge of, attitude towards and practice of oral health	Attitude (negative/positive)	0.895	0.432	0.613
	Knowledge (low/high)	0.058	0.111	0.076
	Knowledge of SFG (yes/no)	0.009	0.038	0.002
	Frequency of tooth brushing (low/high)	0.156	0.145	0.177
	Use of dental floss (yes/no)	< 0.001	< 0.001	< 0.001
	Use of fluoride toothpaste (yes/no/don't know)	0.046	0.168	0.284
Sugar consumption habits[a]		< 0.001	< 0.001	< 0.001
Use of dental services	Dental visit in the past 12 months (yes/no)	0.139	0.742	0.736
	Intention[b]	0.007	0.004	< 0.001

NA, not applicable. [a]Sugar consumption habits were classified based on frequency as low frequency, moderate frequency, relatively high frequency and high frequency. [b]Intention of use of dental services was grouped into four main categories: don't know, treatment, consultation and prevention.

Table 5 Analysis of mean DMFT values according to exposure variables for different age groups.

Variables		*P* value		
		Teenagers	Adults	Overall
Social demographics	Sex (male/female)	0.004[a]	0.004[a]	< 0.001[a]
	Region (less developed area/developed area)	0.203[a]	0.042[a]	0.718[a]
	Nationality (Han/others)	0.041[a]	0.004[a]	0.009[a]
	Parental education level (low/medium/high)	0.379[b]	NA	NA
	Educational level (low/medium/high)	NA	0.057[b]	NA
Knowledge of, attitude towards and practice of oral health	Attitude (negative/positive)	0.127[a]	0.784[a]	0.313[a]
	Knowledge (low/high)	0.246[a]	0.306[a]	0.091[a]
	Knowledge of SFG (yes/no)	0.342[a]	0.142[a]	0.262[a]
	Frequency of tooth brushing (low/high)	0.291[a]	< 0.001[a]	0.974[a]
	Use of SFG (yes/hardly/never)	0.234[a]	0.006[a]	0.007[a]
	Use of dental floss (yes/no)	0.543[a]	0.645[a]	0.298[a]
Use of dental services	Dental visit in the past 12 months (yes/no)	0.008[a]	0.091[a]	0.001[a]
	Intention[c]	0.400[b]	< 0.001[b]	< 0.001[b]

NA, not applicable. [a]Mann-Whitney test for two-categorised variables. [b]A Kruskal-Wallis H test was used for analysis of these factors with three or more categories. [c] Intention of use of dental services was grouped into four main categories: don't know, treatment, consultation and prevention.

Table 6 Multivariate negative binominal regression analysis of the mean DMFT value and SFG chewing habits.

Variable		Model 1[a]	Model 2[b]
		PRR (95% CI)	PRR (95% CI)
Use of SFG	No	1.00 (reference)	1.00 (reference)
	Yes	0.71 (0.61–0.84)***	0.73 (0.62–0.87)***
Sex	Female	NA	1.00 (reference)
	Male	NA	0.71 (0.60–0.85)***
Nationality	Other	NA	1.00 (reference)
	Han	NA	0.65 (0.51–0.83)***
Dental visit in the past 12 months	Yes	NA	1.00 (reference)
	No	NA	0.82 (0.70–0.98)*

[a]Use of SFG was included as the only independent variable. [b]Factors associated with the mean DMFT value were added to model 1.

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

NA, not applicable.

Discussion

The present study identified the level of use of SFG in the survey population. A total of 43.4% of subjects reported that they chewed SFG gum with varying frequencies and SFG-related oral health knowledge and awareness was only 19.4%. The proportion of people in the surveyed population who chew SFG is apparently lower than in some western countries[14-16]. The survey population also had less awareness about the role played by SFG in preventing dental caries compared to that of fluoride (55.7%) and pit and fissure sealant (45.9%). Chewing SFG was also found to be significantly associated with dental caries. According to the 4th NOHS in China, although oral health behaviours have improved in the past 10 years, most citizens still do not brush their teeth twice daily and barely use dental floss, and there were still a large number of untreated caries[4]. Due to the insufficient resources for oral health, inequalities in their distribution and the high economic burden of oral disease[17,18], it is essential to seek oral health behaviours that are easily accessible to individuals, besides the promotion of frequent tooth brushing and flossing.

SFG is an easily accessible and acceptable commodity with a wide variety of flavours for consumers to choose from. Moreover, people can chew SFG almost anytime and anywhere. Not only can chewing SFG relieve stress[19-23] and improve halitosis[24], but the oral care benefits of chewing SFG have also been recognised and supported by a number of regulatory bodies such as the European Association[25], the European Food Safety Authority[26], the FDI[27] and other national dental associations around the world. In recent years, studies on the health economics of SFG have indicated that chewing SFG is a cost-effective method of caries prevention[10,15,28]. The present study focuses mainly on SFG chewing habits and its association with dental caries in China.

In the present study, only 43.4% of the participants chewed SFG, and its preventive effect on caries was not well understood by the public. Sex, region, nationality, parents' level of education, knowledge of SFG, use of dental floss, sugar consumption habits and the intention of dental visits were shown to be related to SFG chewing habits. Among them, the SFG chewing rate was higher in men, people from economically underdeveloped areas and ethnic minorities, which may be due to the greater work- and lifestyle-related pressure experienced by these populations, as studies have found that chewing gum can relieve stress and improve concentration[19-23]. Information on this as a healthy habit may also encourage people to make a change[29], and this may be why people with greater oral health-related knowledge were more likely to chew SFG. Those who used dental floss had a higher chewing rate, perhaps because participants with better oral health promoting behaviours tend to chew SFG. Furthermore, those who consumed sugary foods frequently were more likely to chew SFG, suggesting that the sweetness of SFG may be one of the essential factors that attracts people. The chewing proportion varied widely in adolescents whose parents had different levels of education and in adults with different levels of education. Both adolescents whose parents had a higher level of education and adults with a higher level of education had higher chewing rates. It may be that people with a higher level of education have more access to correct information about oral health, which improves their attitude towards oral health care. A study found that children's oral health behaviours can be influenced by those of their parents[30]; thus, for schoolchildren and teenagers, oral health education should be added into the school curriculum, and also more effort

should be made to strengthen caregivers' oral health knowledge, such as through oral health classes for parents. Those who had a dental visit for prevention or consultation may pay more attention to oral health care and were found to be more likely to chew SFG.

Some studies have shown that those who chew SFG regularly had a lower severity of dental caries[5,6], but researchers had only studied the effect on children (aged 6 to 9 years) in China[31,32]. There is a lack of studies on teenagers and adults, who are the main consumers of SFG. Mean DMFT values reflect lifetime experience of dental caries and the severity of caries in the population examined. After adjusting for factors related to the mean DMFT value, the present study has provided convincing evidence that chewing SFG is a related factor for dental caries.

Some studies have shown that dental visits are one of the important determinants of dental caries experience[33,34]. In the present study, use of dental services was not found to have an influence on SFG consumption but was a crucial factor associated with dental caries experience. In agreement with previous studies[33,34], those who had a history of dental visits had a higher DMFT value, indicating that treatment-related care is still more common in China than prevention-orientated care. Most individuals only seek help from dentists when suffering from a toothache or other symptoms. On the one hand, it may be that the public do not realise the importance of caries prevention, especially through professional dental care, which leads indirectly to a substantial increase in the cost of caries treatment, creating a huge economic burden[18,35]. According to the WHO, dental caries has become the fourth most expensive chronic disease to treat in the world[1]. On the other hand, the limited oral health resources and services in China prevent residents from accessing professional dental care. However, dental visits cannot be considered a risk factor because the act of attending a dental visit is the result of caries experience[36].

The present study has some limitations. First, the prevalence and mean DMFT value for permanent dental caries in teenagers were higher than that reported in the 4th NOHS in China, whereas the same indicator in adults was lower[4]. This may be because compared with the 4th NOHS, fewer areas were included in the present survey and the sample size was smaller, and urban and rural areas were distributed unevenly. Second, the present study was cross-sectional, so causality between caries and related factors including chewing SFG could not be obtained directly. Randomised controlled trials about the effect of the mastication time and volume of SFG chewed on dental caries could be designed in the future.

Conclusion

Based on the current status of dental caries in China, relevant departments could consider chewing SFG as a possible supplement to the existing caries prevention strategies. However, it is important to emphasise that chewing SFG is no substitute for traditional oral health practices, such as tooth brushing and flossing. Under the ambitious goal of "Healthy China 2030", the Oral Health Plan (2019-2025) should be implemented to protect the public's oral health.

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Conflicts of interest

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

Author contribution

Drs Chun Zi ZHANG, Shuo DU, Wen Hui WANG, Jian LIU, Chao YUAN and Yi Zhen YU analysed the data; Drs Chun Zi ZHANG and Shuo DU drafted the paper; Drs Yan SI and Shan Shan ZHANG conceived the programme of research and critically revised the manuscript. All the authors read and approved the final version for submission.

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