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History of Frequent Gum Chewing Is Associated with Higher Unstimulated Salivary Flow Rate and Lower Caries Severity in Healthy Chinese Adults

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Key Words

Adults · Caries · Chewing gum · Salivary flow

Abstract

This was a single-center, prospective, cross-sectional study stratified by age and gender with the objective of determining the relationship between gum chewing history, salivary flow, and dental caries severity in adults. We enrolled 191 subjects aged 18–65 years who underwent assessments for gum chewing history, unstimulated salivary flow rate, salivary pH, and caries severity. Unstimulated salivary flow rate tended to decline with increasing age ($p = 0.04$), and significant differences in unstimulated salivary flow rate were also found for males (0.58 ± 0.32 ml/min) versus females (0.48 ± 0.30 ml/min) ($p = 0.02$). Weekly gum chewing frequency was greater in younger subjects ($p = 0.001$) while no age group differences were noted in pieces per day or chewing duration. Gum chewing habits were similar in males and females. A multivariate model demonstrated that only days per week chewing gum ($p < 0.001$) and gender ($p = 0.007$) were predictive of unstimulated salivary flow rate ($R^2 = 0.40$). Mean caries severity scores, assessed via ICDAS II and DMFT, increased with age. In multivariate analysis, age was positively associated with ICDAS ($p = 0.001$) and days per week chewing gum was negatively associated with ICDAS ($p = 0.004$), indicating that caries severity increased with age, and that days of chewing provided an inverse effect, with increased days of chewing being associated with decreased severity of caries. Overall, a history of frequent gum chewing is associated with higher unstimulated salivary flow rate and lower caries severity.

Dental caries is the localized destruction of susceptible dental hard tissues by acidic by-products resulting from bacterial fermentation of dietary carbohydrates [Selwitz et al., 2007]. The average American has 12 teeth and 38 tooth surfaces that are either decayed, missing, or filled. Extensive tooth loss interferes with mastication and may negatively impact food choices. Furthermore, poor oral health is strongly linked to a number of comorbid conditions including ischemic heart disease [Joshipura et al., 1996], respiratory disease [Scannapieco, 1999], diabetes mellitus [Shlossman et al., 1990], and ischemic stroke [Joshipura et al., 2003]. Continued advancements in dental caries prevention strategies are warranted.

Saliva serves numerous functions including lubrication of the oral tissues, protecting the oral tissues during mastication, initiation of carbohydrate digestion, antibacterial activities, and maintenance of an acid-buffering en-

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vironment in the oral cavity; this latter function is critical in the prevention of caries. When carbohydrates are consumed, the metabolism of carbohydrate results in the production of acidic by-products that demineralize enamel and dentin. Once oral carbohydrate metabolism is complete, the pH of dental plaque rises back to normal within several minutes in the presence of saliva, due to the presence of salivary pH buffering agents. When plaque is exposed to low salivary flow, the time needed to return to normal pH is prolonged, which leads to a longer period of dental and enamel demineralization [Stookey, 2008]. On a chronic basis, low salivary flow may lead to dental caries development. Conversely, stimulation of salivary flow shortens the time needed to return to normal pH and, therefore, chronically higher salivary flow rates may hinder dental caries development [Edgar and Higham, 2004].

Salivary flow is stimulated and plaque pH is increased when gum is chewed acutely [Dong et al., 1995; Polland et al., 2003; Dawes and Kubieniec, 2004; Dawes, 2005; Ribelles Llop et al., 2010] or multiple times per day over up to 2 weeks [Jenkins and Edgar, 1989; Dodds et al., 1991]. While the effects of short-term gum chewing are known to stimulate salivary flow, longer-term gum chewing effects are unknown. Further, the act of mastication is known to remove fermentable substrate from the oral cavity and enhance remineralization [Imfeld, 1999]. The purpose of this cross-sectional study was to determine the relationship between gum chewing history, salivary flow, and dental caries severity in adults. We hypothesized that a history of frequent gum chewing would be associated with a higher unstimulated salivary flow rate and, secondarily, a lower caries severity.

Subjects and Methods

Ethics

The protocol for this clinical trial (No. 10-SBC-09-WRI-01) was approved by the Shanghai Nutrition Society Institutional Review Board (Shanghai, China) and all enrolled subjects were volunteers who provided written informed consent. This research was conducted in accordance with the Declaration of Helsinki.

Trial Design

This was a single-center, prospective, cross-sectional study stratified by age and gender with the objective of determining the relationship between gum chewing history, salivary flow, and dental caries severity in adults.

Participants

Subjects were recruited from the Affiliated Stomatology Hospital of Tongji University (Shanghai, China). Inclusion criteria for this trial included men and women ages 18–65 years, self-reported regular consumption of a traditional Chinese diet, and willingness to comply with study requirements. Exclusion criteria included any clinically significant systemic disease (e.g. diabetes mellitus, coronary artery disease, cancer); regular use of tobacco in any form; regular intraoral appliance use; medication use that affects salivary production; pregnant or lactating female; history of alcohol, drug, or medication abuse, and participation in another study with any investigational product within 3 months of screening.

Stratification

Enrollment into the study was stratified by age and gender. Age strata were 18–30, 31–40, 41–50, and 51–65 years. With each age stratum, 48 subjects (24 males and 24 females) were anticipated with the exception of the 51- to 65-year stratum (24 males and 23 females).

Methodology

Subjects were screened for inclusion and exclusion criteria and were asked questions to collect demographic, medical history, and concomitant medication information. Premenopausal and perimenopausal females underwent urinary pregnancy tests. Eligible subjects underwent all study-related tests immediately thereafter on the same day.

Caries Severity. Caries severity was assessed using the ICDAS II criteria [International Caries Detection and Assessment System Coordinating Committee, 2005]. Before subject enrollment, each investigator completed training through the e-learning program released by ICDAS organization through its website in a 90-min session (http://icdas.smile-on.com). The training included both a theoretical section and evaluation of projected images of carious teeth. Prior to the examinations, the teeth were flossed and brushed by a dental hygienist and then dried with an air syringe. The teeth were examined by a single examiner with the aid of a light reflector and a 3-in-1 air syringe. The criterion for diagnosis of caries according to ICDAS was a score of 3 or greater. Decayed, missing, filled teeth (DMFT) was assessed for all 32 teeth. DMFT was calculated as the number of teeth with caries lesions (incipient caries not included) ('D', for decayed), teeth that had been extracted ('M', for missing), or had fillings or crowns ('F'). The sum of the three figures formed the DMFT value. The maximum possible DMFT value was 32.

Gum Chewing History. Frequency and duration of gum chewing over the previous year was assessed using a questionnaire consisting of three questions. The first question asked was: 'Over the previous year, how many days per week did you chew gum?' A 6-point ordinal scale was used to categorize responses as follows: 0 = never or less than once per month, 1 = 1–3 days per month, 2 = 1 day per week, 3 = 2–3 days per week, 4 = 4–5 days per week, or 5 = 6–7 days per week. The second question asked was: 'Over the previous year, on days when you chewed gum, how many pieces of gum did you chew each day?' A 5-point ordinal scale was used to categorize responses as follows: 0 = never or less than once per day, 1 = 1 piece per day, 2 = 2–3 pieces per day, 3 = 4–5 pieces per day, or 4 = 6 or more pieces per day. The final question asked was: 'Over the previous year, when you chewed gum, how many minutes did you chew?' Subjects provided a continuous numerical response to this question.

Unstimulated Salivary Flow Rate. Subjects were instructed to refrain from food, gum, tobacco, and drink for at least 2 h and from alcohol for at least 12 h before testing. Unstimulated salivary flow rate was assessed over a 5-min period using the methodology of Dawes [1972]: the subject swallowed residual saliva before the beginning of the collection and, with the head down and mouth slightly open, saliva was allowed to drip from the mouth, through a small plastic funnel, and into a graduated 10-ml centrifuge tube in ice water. In the last few seconds of the 5-min period, subjects spat any remaining saliva accumulated in the mouth into the plastic funnel. No other conscious movements of the oral musculature were made during the collection. The volume of saliva samples was recorded to the nearest 0.1 ml and flow rates (ml/min) were calculated.

Salivary pH. Salivary pH was measured with a pH meter. For this test, 1 ml of saliva was dropped onto the pH meter electrode for three consecutive measurements. The final salivary pH value was recorded as the average of the three measurements. Testing of salivary pH was initiated as soon as possible (<1 min) following the unstimulated salivary flow rate test.

Sample Size

We performed a power analysis (PASS 2008, NCSS, Kaysville, Utah, USA) assuming a two-sided alpha of 0.05, statistical power of 80%, and a minimum detectable correlation between gum chewing history and unstimulated salivary flow of r = 0.2. A sample size of 191 subjects was deemed sufficient based on these parameters.

Statistical Methods

All data were recorded on study-specific data forms, double-entered into a validated database, and verified for accuracy. Summary statistics for salivary flow rate were calculated by age and gender. Associations of the independent variables and covariates, including gum chewing history, gender, age, and body mass index with unstimulated salivary flow were investigated using univariate analysis and CART software (Salford Systems, San Diego, Calif., v. 6.0, 2008). Variables identified by CART and/or univariate analysis as possibly significantly associated with salivary flow were then used in a multiple regression model (SAS/STAT software, Cary, N.C., v. 9.1, 2008). The possibility of significant statistical interactions between the independent and dependent variables and covariates was also explored. Regression coefficients and p values from the t tests of each independent variable were computed. As the variables were measured in different units of measurement, standardized coefficients were obtained by transforming the variables into z scores before running the regression; thus, all of the variables were reported on the same scale. An analysis of variance table, showing the effects of gum chewing history, age, gender, and body mass index on unstimulated salivary flow, was prepared. The associations of unstimulated salivary flow with caries severity (ICDAS II and DMFT) and salivary pH were also examined.

The caries severity of subjects was evaluated using the ICDAS II and DMFT systems. Each of the ICDAS II scores contains two digits, with the first digit describing the restoration/sealant condition of a tooth, and the second digit describing caries severity. In the analysis of caries severity only the second digit, describing caries severity, was used, and this caries code was treated as blank if the tooth was missing. A mean score for 32 teeth (or fewer, if teeth were missing) for each subject was calculated. At the same examination the number of teeth that had caries lesions (not including incipient caries) ('D'), or were missing ('M'), or had fillings or crowns ('F') was calculated using the DMFT system. A regression model was constructed to evaluate the relationship of gum chewing history with salivary pH and dental caries severity (ICDAS II and DMFT).

Because the subjects were divided among three investigators (A, B, and C) for their dental examinations, interrater reliability of the ICDAS II scoring system was examined in a subset of 30 randomly selected subjects who were examined independently in randomized order by all three investigators using the ICDAS II scoring system. The interrater reliability (A vs. B vs. C) of the ICDAS II scores was assessed using Fleiss's kappa statistic to quantify the level of agreement among investigators examining the same subject on the same day. The reliability analysis examined investigator agreement for each major ICDAS parameter and for tooth-specific scores given to randomly selected teeth.

Results

Subject Disposition

Of the 665 subjects who were screened for participation in the study, 474 were deemed ineligible based on inclusion and exclusion criteria evaluation. The remaining 191 subjects were enrolled in the study.

Recruitment

Subjects were enrolled in this trial between March 2011 and April 2011. Subjects underwent a single day of testing and were not followed beyond this period. All subjects completed the entire testing battery.

Subject Characteristics, Salivary Flow Rate, and Gum Chewing History

Subject demographics and physical characteristics are detailed by age stratum in table 1. Gum chewing frequency was greater in younger subjects (p = 0.001) while no age group differences were noted in pieces per day or chewing duration. Gum chewing habits were similar in males and females (table 2). Unstimulated salivary flow rate tended to decline with increasing age (p = 0.04), and significant differences in unstimulated salivary flow rate were also found for males (0.58 ± 0.32 ml/min) versus females (0.48 ± 0.30 ml/min, p = 0.02) (table 3).

Interrater Reliability of ICDAS Scoring

The interrater reliability of ICDAS scores was high, with a Fleiss's kappa statistic of 0.80, indicating excellent agreement between raters.

Factors Associated with Salivary Flow

Relationship of Unstimulated Salivary Flow Rate with Gum Chewing History, Gender, and Age. Univariate analyses showed significant positive relationships of

Table 1. Baseline subject characteristics

Variable	18–30 years (n = 48)	31–40 years (n = 48)	41–50 years (n = 48)	51–65 years (n = 47)
Male gender	24 (50.0)	24 (50.0)	24 (50.0)	24 (51.1)
Age, years	26 ± 3	34 ± 3	45 ± 3	56 ± 4
Height, cm	169 ± 7	169 ± 8	167 ± 8	166 ± 8
Weight, kg	62 ± 9	66 ± 12	66 ± 10	67 ± 10
Body mass index, kg/m^2	22 ± 2	23 ± 3	24 ± 2	24 ± 2

Values are mean ± SD or n (%).

Table 2. Gum chewing history over the previous year in study subjects

Variable	18–30 years (n = 48)	31–40 years (n = 48)	41–50 years (n = 48)	51–65 years (n = 47)
Chewing gum frequency				
Never or less than once per month	5 (10.4)	8 (16.7)	6 (12.5)	9 (18.8)
1–3 days per month	3 (6.3)	1 (2.1)	4 (8.3)	8 (16.7)
1 day per week	0 (0)	2 (4.2)	2 (4.2)	2 (4.2)
2–3 days per week	9 (18.8)	11 (22.9)	21 (43.8)	19 (39.6)
4–5 days per week	15 (31.3)	17 (35.4)	11 (22.9)	7 (14.6)
6–7 days per week	16 (33.3)	9 (18.8)	4 (8.3)	2 (4.2)
Pieces of gum chewed per day				
Never or less than 1	5 (10.4)	8 (16.7)	6 (12.5)	9 (19.2)
1	12 (25.0)	12 (25.0)	16 (33.3)	19 (40.4)
2–3	26 (54.2)	26 (54.2)	25 (52.1)	17 (36.2)
4–5	5 (10.4)	2 (10.4)	1 (2.1)	2 (4.3)
6 or more	0 (0)	0 (0)	0 (0)	0 (0)
Chewing duration, min	18 ± 13	14 ± 14	13 ± 10	17 ± 17

Values are mean ± SD or n (%).

Table 3. Oral health parameters in study subjects

Variable	18–30 years (n = 48)	31–40 years (n = 48)	41–50 years (n = 48)	51–65 years (n = 47)
Unstimulated salivary flow, ml/min	0.61 ± 0.33	0.56 ± 0.31	0.50 ± 0.30	0.44 ± 0.28
Salivary pH	6.98 ± 0.33	6.92 ± 0.33	6.89 ± 0.34	6.84 ± 0.33
Caries severity				
ICDAS	0.39 ± 0.28	0.47 ± 0.41	0.65 ± 0.46	0.75 ± 0.48
DMFT	4.7 ± 3.1	5.5 ± 4.0	7.7 ± 5.0	9.8 ± 4.4

Values are mean ± SD.

Table 4. Multiple regression model to evaluate the effects of gum chewing history on unstimulated salivary flow rate

Variable	Beta	t	p value
Intercept	–	3.318	0.001
Days per week	0.609	10.759	<0.001
Gender (1 = male, 0 = female)	0.154	2.731	0.007

days per week ($\beta = 0.61$, $p < 0.001$), pieces per day ($\beta = 0.49$, $p < 0.001$), and minutes per chewing episode ($\beta = 0.21$, $p < 0.01$) with unstimulated salivary flow rate. When these independent variables were included in a multiple regression model, together with the covariates age and gender, only days per week and gender were independently associated with unstimulated salivary flow. As shown in table 4, greater frequency of gum chewing and male gender were associated with higher salivary flow rates. The multiple regression model had an R^2 value of 0.40, indicating that a relatively large proportion of the variation in unstimulated salivary flow rate in this subject group can be attributed to days per week of gum chewing and gender. An interaction between days per week and gender was examined, and found to be not significant.

Relationship of Unstimulated Salivary Flow Rate with Salivary pH. Mean salivary pH declined slightly with increasing age (table 3). Univariate analyses showed a significant positive relationship between unstimulated salivary flow rate and salivary pH, indicating that the salivary pH increased (i.e., became less acidic) as salivary flow rate increased. A multiple regression model indicated the p value for this association to be <0.001. Gender and gum chewing history variables were tried in the model, as were interaction terms, and did not provide significant additional information.

Relationship of Gum Chewing History with Caries Severity. Mean caries ICDAS II and DMFT scores increased with age. In a univariate analysis of ICDAS II score versus gum chewing history and age, only age was statistically significantly associated with ICDAS score ($p = 0.001$). However, in a multiple regression model age was positively associated with ICDAS ($p = 0.001$) and days per week was negatively associated with ICDAS ($p = 0.004$), indicating that caries severity increased with age, and that days of chewing provided an inverse effect, with increased days of chewing being associated with decreased severity of caries.

Discussion

This cross-sectional study demonstrated that frequent gum chewing over the previous year, presumably a proxy for lifetime gun-chewing history, was associated with a higher unstimulated salivary flow rate and a lower caries severity. In particular, chewing gum on more days per week had a consistent relationship with elevated unstimulated salivary flow rate and lower caries severity. However, the number of pieces chewed per day and the average duration of chewing gum was not related to any outcomes of interest once days of chewing were accounted for in the various models.

The effects of gum chewing on oral health are conflicting, although most studies report positive benefits of gum chewing. Chewing four sticks of sugar-free gum per day for 8 weeks increased unstimulated salivary flow rates and maintained these elevated rates for 8 more weeks following discontinuation from the study [Jenkins and Edgar, 1989]. Similarly, chewing sugar-free gum for 10 min during every waking hour for 2 weeks increased pH and buffering capacity of unstimulated whole saliva and increased stimulated parotid saliva flow rate [Dodds et al., 1991]. However, others have reported no impact of gum chewing on salivary flow rates [Aguirre-Zero et al., 1993].

An important distinction of the current study was the measurement of unstimulated salivary flow rates, not stimulated whole saliva or parotid saliva. In fact, the unstimulated flow rate has the greatest contribution to total salivary output during the diurnal cycle [Sreebny, 1989]. The potential mechanism of action for the oral benefits associated with higher unstimulated salivary flow rates is that unstimulated flow is primarily attributable to the submandibular gland, which produces mucin-rich saliva that coats the oral tissues. Mucins prevent desiccation, provide lubrication, bind to toxins, and agglutinate bacteria – all of which are believed to contribute to improved oral health [Dodds et al., 2005]. Dawes [1983], in a mathematical model, postulated that the unstimulated saliva flow rate was one of the most important determinants of sugar clearance from the oral cavity and, in an artificial mouth model, very low saliva flow rates were associated with more profound and longer pH changes in the bacterial compartment, further emphasizing the importance of a healthy unstimulated saliva flow rate in preventing demineralization [Lagerlöf et al., 1984].

Strengths of the study included recruitment of a wide age range of subjects, use of the validated instruments ICDAS II and DMFT to assess caries severity, appropriately powered design, and demonstration of excellent inter-rater agreement among the three investigators who carried out the study and performed the caries assessment. Limitations of the study included the cross-sectional design, which cannot demonstrate causality, and the racial homogeneity of the subjects, which limits the generalizability of the study findings. Furthermore, gum chewing history was determined by self-report over the previous year using an unvalidated instrument. However, no known assessment tool currently exists to evaluate gum chewing history. The recall period was limited to 1 year since recalling gum chewing habits over longer periods would likely result in inaccurate data. Finally, we did not collect data regarding the type of gum chewed, again due to expected inaccuracies in self-reporting. Although sugar-free and sugar-containing gum stimulate salivary flow equally well [Dawes and Macpherson, 1992; Dawes and Dong, 1995], sugar-containing gum is known to lower plaque pH and increase caries risk with habitual use [Imfeld, 1999]. Therefore, the relationship of gum chewing with caries severity may be obscured by the type of chewing gum preferred by the subjects.

In conclusion, frequent gum chewing is associated with higher unstimulated salivary flow rates and a lower caries severity. Additional research is warranted to determine if the beneficial relationships of frequent gum chewing observed in this study are confirmed in prospective longitudinal gum chewing studies.

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Disclosure Statement

M.W.J.D. and A.B.H. are employees of Wm. Wrigley Jr. Co. (Chicago, Ill., USA), which provided financial support for this study. This group was involved in study design, critical review of the manuscript, and the decision to publish.

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