J Clin Periodontol 2006; 33: 31–36 doi: 10.1111/j.1600-051X.2005.00862.x

Journal of Clinical Periodontology

Oral malodor-related parameters in the Chinese general population

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Liu XN, Shinada K, Chen XC, Zhang BX, Yaegaki K, Kawaguchi Y. Oral malodor-related parameters in the Chinese general population. J Clin Periodontol 2006; 33: 31–36. doi: 10.1111/j.1600-051X.2005.00862.x. © Blackwell Munksgaard, 2006.

Abstract

Objectives: To estimate the prevalence of halitosis in the Chinese population and to assess the relationships between halitosis and oral health, social and behavioural factors.

Methods: The correlation between the incidence of oral malodor and oral health was surveyed in a sample of 2000 individuals (1000 males and 1000 females) aged 15–64 years residing in urban and rural areas. Malodor was measured with both organoleptic measurements and with a portable sulphide monitor. Assessment of oral health included decayed, missing and filled teeth (DMFT), periodontal status, dental plaque, and tongue coating. Behavioural and social factors related with oral health or halitosis were also investigated.

Results: The prevalence of halitosis was 27.5% according to the organoleptic score. The level of volatile sulphur compounds (VSCs) in mouth air was significantly lower in males and in some of the age groups after lunch. Age and location of residence (rural or urban areas) did not influence the VSCs concentration in mouth air. The amount of tongue coating played the most important role in increasing VSCs concentration in mouth air, followed by periodontal status and plaque index values. DMFT, social, and behavioural factors did not contribute to halitosis.

Conclusions: Tongue coating score, modified sulcus bleeding index and calculus index were factors significantly related to oral malodor in this study.

Key words: epidemiology; oral malodor; periodontology; tongue coating; volatile sulphur compunds concentration

Accepted for publication 3 October 2006

The most frequent sources of halitosis that exist in the oral cavity (Delanghe et al. 1997) include bacterial reservoirs such as the dorsum of the tongue, saliva and periodontal pockets. The prominent elements of oral malodor are volatile sulphur compounds (VSCs) (Tonzetich 1977). Tongue coating and periodontal pockets play important roles in the production of VSCs (Yaegaki & Sanada 1992a). A recent oral health survey in China found that periodontal conditions were not optimistic in the Chinese population (Wang et al. 2002). Among adults between the ages of 35 and 44 years, 94.2% had gingival bleeding and calculus. Severe periodontal conditions were relatively rare. With the unfavourable periodontal conditions observed, it could be assumed that the prevalence of halitosis might also be high. However, this aspect has never been investigated among the Chinese population. In addition, oral health status, which affects oral malodor production, was reported to be associated with health behaviour or socioeconomic factors (Axelsson 2004). We, therefore, investigated the relationship between halitosis and these factors or behaviour.

Recent development of the Halimeter® (Interscan, Chatsworth, CA, USA) has led to an unprecedented increase in halitosis research because of its convenience, portability and reproducibility (Rosenberg et al. 1991, Miyazaki et al. 1995, Murata et al. 2002, Carvalho et al. 2004). Although organoleptic procedures are the most popular way of measuring oral malodor, they are not objective. In the present study, the analysis of oral malodor and related parameters was conducted mainly with VSCs concentration.

The purpose of this study was to estimate the prevalence of halitosis in a Chinese population and to assess the relationship between halitosis and oral health status, socioeconomic factors and health behaviour by employing standardized procedures for measurement of halitosis.

Methods

Study design

Two thousand subjects from the ages of 15–64 years were assessed between October and December 2002, at four districts in Beijing, China. The sampling method of the National Epidemiological Survey on Oral Health in China (Wang et al. 2002) was used in this study. The subjects were sampled by a stratified, cluster method and invited to examination facilities, where 1000 subjects

(500 males and 500 females) were sampled from urban areas and another 1000 from rural areas. From each area, 1000 subjects were selected so that there was the same number of subjects (200) in each of five age groups (15–24, 25–34, 35–44, 45–54, and 55–64 years of age). For analysis, the data were divided by area of residence: urban and rural groups. All the subjects were informed of the purpose of the survey and had voluntarily consented to the examination. All the data were analysed anonymously. Before the survey, a pilot trial was conducted to calibrate examiners and to modify the questionnaire.

Examination procedures

Two trained dentists assessed the subjects' oral health status and halitosis levels independently. One examiner evaluated the VSCs, tongue coating score (TCS), organoleptic score (OS) and decayed, missing and filled teeth (DMFT), while the other was in charge of the periodontal examination. The intra-examiner agreement (κ statistics) of DMFT was 0.95 and that of PD was 0.72. The subjects were instructed to refrain from eating, drinking, smoking, brushing, and rinsing their mouths for 2 h before the examination. They were asked to fill in a questionnaire that included 54 questions in seven main categories: socioeconomic status (education, etc., five questions), oral hygiene habits (toothbrushing, etc., 13 questions), knowledge of oral health (10 questions), dental visit pattern (six questions), habits (smoking, etc., eight questions), medical history (one question) and self-reported halitosis (11 questions). All subjects were examined between 08:00 and 12:00 hours and between 13:00 and 17:00 hours. For analysis, the subjects were divided into four time groups: 08:00–10:00 hours, 10:00–12:00 hours, 13:00–15:00 hours and 15:00–17:00 hours. The concentration of VSCs was measured using the Halimeter®. The subjects were asked to breathe through their nose during measurement. Before starting each survey, the Halimeter® was calibrated with 250 parts per billion (ppb) H_2S according to manufacturer's instructions. The manufacturer's instructions were followed for all measurement procedures with the Halimeter®. The maximum values for the VSCs were determined in ppb by direct reading from the digital display on the monitor. Halitosis was evaluated based on the same standard or definition mentioned in previous reports (Yaegaki & Sanada 1992b, Miyazaki et al. 1995) and in the manufacturer's instruction (http://www.halimeter.com/halcal.htm). The former standard defined that less than 75 ppb was normal, whereas 110 ppb or less was considered normal in the manufacturer's instructions.

The OS was also determined to evaluate malodor. The sense of smell of the examiners was also standardized for the organoleptic measurements using the T&T olfactometer™ (Daiichi Yakuhin Sangyo Co., Tokyo, Japan) (Kawamoto et al. 2002, Murata et al. 2002). The system consists of five compounds eliciting odors. Each compound is graded as eight concentrations from −2 to 5. A test paper strip is dipped into the odor solution and is used to evaluate the examiner's sense of smelling. The T&T score of the examiner was rated as normal. The subjects were instructed to exhale briefly through the mouth, at a distance of approximately 10 cm from the nose of the examiner. A privacy screen with a hole was placed between the subject and the examiner. Data were recorded on a scale of 0–5, and score 2 or over was diagnosed as halitosis (Murata et al. 2002). The oral examination included determining the DMFT, plaque index (PI) (Quigley & Hein 1962), modified sulcus bleeding index (mSBI) (Newbrun 1996), calculus index (CI) (Greene & Vermillion 1964), PD, and TCS. All factors were assessed with an oral mirror and a Community Periodontal Index (WHO/CPI) probe (Shanghai Dental Instrument Manufacturer, Shanghai, China), which was recommended by the World Health Organization under artificial light. Dental examination was performed on all teeth after the halitosis measurements at each appointment. PI, mSBI, and PD were assessed at the sites of tooth numbers 16, 21, 24, 36, 41, and 44 (Ramfjord 1959). The highest CI score for the six sites was recorded. TCS was evaluated on a scale of 0–3 by inspecting the area of the tongue coating (0, no coating apparent; 1, less than 1/3 of the area of tongue dorsum coated; 2, between 1/3 and 2/3 of the surface covered; 3, more than 2/3 of the surface coated) (Oho et al. 2001).

Statistics

Statistical analysis was carried out using SPSS 10.0E software (SPSS Inc., Chicago, IL, USA). Independent sample *t*-tests were used to detect differences in the mean VSCs values of gender, locale, and time of day within each age group. One-way analysis of variance (ANOVA) with post hoc Bonferroni's multiple comparison was used to determine the mean VSCs values of assessment time and each questionnaire category for a combination of all age groups. Pearson's correlation was used to determine the association between VSCs and oral health in different age groups. The variables that showed significant differences in the independent sample *t*-tests, ANOVA, and Pearson's correlations were assessed by logistic regression. Odd ratios of VSCs-related factors were also calculated.

Results

We found that 27.5% of the population had halitosis when we employed the OS measurement. On the other hand, 20.3–35.4% of the subjects exhibited VSCs values higher than 110 ppb (http://www.halimeter.com/halcal.htm) and 75 ppb which are considered the limit of social acceptance by Miyazaki et al. (1995), Yaegaki & Sanada (1992b) and van Steenberghe & Quirynen (2003).

Table 1 showed that there were no significant differences among mean values for the VSCs of the different age groups, nor between subjects from the urban and rural areas. There were statistically significant differences in the mean values of the VSCs between males and females of the 35–44-year age group. In the 15–24-, 25–34-, and 55–64-year age groups, values for the VSCs were significantly greater during the assessment period from 10:00– to 12:00 hours (before lunch) when compared with those in the period from 13:00– to 15:00 hours (after lunch). However, there were no significant differences among subjects in the other three assessment periods.

Table 2 shows the Pearson correlation coefficients between VSCs values and oral health by age group. VSCs were strongly correlated with OS in all age groups ($p < 0.01$). Significant correlations were also found between VSCs and TCS for all the age groups. Significant correlations were observed between VSCs and PI for most age groups. Regarding periodontal status, VSCs were significantly correlated with mSBI, CI, and PD in most age

Table 1. VSCs distribution by age group based on gender, locale, and time

	VSCs (ppb, mean (standard deviation))				
Age (years)	15–24	25–34	35–44	45–54	55–64
Number	400	400	400	400	400
Gender					
Male	79.83 (62.30)	79.95 (78.00)	72.00 (56.31)]*	77.33 (67.47)	84.14 (77.70)
Female	68.78 (53.59)	96.38 (88.72)	86.97 (86.53)]*	82.53 (83.90)	87.14 (86.10)
Locale					
Urban	68.65 (53.46)	86.17 (77.37)	76.75 (62.64)	76.75 (76.50)	89.71 (88.33)
Rural	80.08 (62.45)	90.00 (90.01)	82.37 (82.84)	83.05 (75.76)	81.45 (74.77)
Time					
08:00–10:00 hours	77.06 (55.21)	86.74 (84.98)	89.28 (106.76)	78.95 (69.96)	84.60 (79.13)
10:00–12:00 hours	87.94 (70.22)]*	101.75 (81.27)]*	76.00 (62.84)	90.03 (87.05)	101.32 (96.57)]*
13:00–15:00 hours	56.70 (40.80)]*	59.09 (42.99)]*	70.69 (47.39)	76.10 (83.64)	68.45 (39.10)]*
15:00–17:00 hours	73.39 (54.97)	92.20 (101.70)	82.75 (63.02)	67.79 (49.93)	77.57 (88.16)
Average	74.39 (58.36)	88.06 (83.77)	79.58 (3.48)	79.94 (76.10)	85.65 (81.94)

*Significant difference ($p < 0.05$) between paired items within each age group.

Table 2. Pearson correlations between volatile sulphur compounds (VSCs) and oral status by age group

	VSCs				
Age (years)	15–24	25–34	35–44	45–54	55–64
Number	400	400	400	400	400
OS	0.510**	0.234**	0.438**	0.476**	0.483**
TCS	0.216**	0.241**	0.236**	0.147**	0.202**
PI	0.210**	0.081	0.107*	0.122*	0.115*
CI	0.203**	0.206**	0.156**	0.200**	0.035
PD	0.118*	0.251*	0.162**	0.149**	0.018
mSBI	0.106*	0.302**	0.220**	0.207**	0.020
DT	0.093	0.055	0.007	− 0.028	0.094
MT	− 0.019	0.035	0.033	− 0.052	0.033
FT	− 0.065	− 0.012	− 0.053	− 0.056	− 0.056
DMFT	0.037	0.035	− 0.014	− 0.071	0.045

*$p < 0.05$,
**$p < 0.01$.
OS, organoleptic score; TCS, tongue coating score; PI, plaque index; CI, calculus index; PD, pocket depths; mSBI, sulcus bleeding index; DT, decayed teeth; MT, missing teeth; FT, filled teeth; DMFT, decayed, missing and filled teeth.

Table 3. Pearson correlations between organoleptic score (OS) and oral status by age group

	OS				
Age (years)	15–24	25–34	35–44	45–54	55–64
Number	400	400	400	400	400
TCS	0.205**	0.278**	0.290**	0.311**	0.198**
PI	0.154**	0.208**	0.161**	0.232**	0.262**
CI	0.244**	0.260**	0.205**	0.294**	0.203**
PD	0.189**	0.311**	0.271**	0.184**	0.168**
mSBI	0.212**	0.218**	0.160**	0.118**	0.144**
DT	0.043	0.065	− 0.070	− 0.028	0.064
MT	0.032	0.016	0.054	− 0.091	− 0.003
FT	− 0.047	− 0.091	− 0.054	− 0.123*	− 0.112*
DMFT	0.014	− 0.023	− 0.039	− 0.127*	− 0.018

*$p < 0.05$.
**$p < 0.01$.
TCS, tongue coating score; PI, plaque index; CI, calculus index; PD, pocket depths; mSBI, sulcus bleeding index; DT, decayed teeth; MT, missing teeth; FT, filled teeth; DMFT, decayed, missing and filled teeth.

groups. The remaining measurements (DT, MT, FT, and DMFT) were not correlated with VSCs for any of the age groups. With respect to OS, 27.5% of the subjects scored 2 or higher. Also, OS was significantly correlated with TCS, PI, mSBI, CI, and PD for all age groups (Table 3).

We also investigated the subjects' behaviour and attitudes towards oral health. The subjects who brushed their teeth in the evening (mean 78.54, SD 71.14) demonstrated significantly lower VSCs scores than those who only brushed in the morning or never brushed (mean 86.44, SD 81.11) ($p < 0.05$). However, mean VSCs values did not show significant differences in other items such as social conditions, knowledge of oral health, frequency of dental visits, behavioural factors or medical history.

In this population, 43.5% of the males and 10.5% of the females reported smoking daily. However, VSCs concentration in mouth air did not correlate with smoking habit (data not shown).

Logistic regression analysis was conducted based on the bivariable analysis (Table 4). TCS, gender, CI and mSBI were significantly associated with VSCs. TCS had the highest odds ratio value (1.81), followed by mSBI (1.41), gender (1.37), and CI (1.18). However, time of day, PI, PD, and brushing in the evening were not associated with VSCs.

Discussion

Examination of halitosis

OS is the gold standard for evaluating halitosis, although it lacks objectivity

Table 4. Results of logistic regression analysis of volatile sulphur compounds (VSCs) concentration ($n = 2000$; VSCs: 0: $\leqslant 75$ ppb, 1: > 75 ppb)

Variable	Variables encoding	Number	*B*	SE (95% CI)	OR	*P*
PD	1: < 3.5 mm	1418	-0.21	0.11 (0.66, 1.00)	0.81	0.050
	2: 3.5–5.5 mm	532				
	3: > 5.5 mm	50				
mSBI	1: < 0.5	1020	0.34	0.09 (1.18, 1.68)	1.41	0.000
	2: 0.5–1	708				
	3: > 1	272				
CI	1: < 1	452	0.17	0.07 (1.03, 1.36)	1.18	0.020
	2: 1–2	1390				
	3: > 2	158				
PI	1: < 2	230	0.11	0.09 (0.95, 1.32)	1.12	0.185
	2: 2–3	1108				
	3: > 3	662				
Brushing in the evening	0: No	259	-0.17	0.10 (0.69, 1.04)	0.86	0.104
	1: Yes	1741				
Gender	1: Male	1000	0.31	0.10 (1.12, 1.67)	1.37	0.002
	2: Female	1000				
Time	1: 08:00–10:00 hours	481	-0.04	0.04 (0.89, 1.05)	0.97	0.413
	2: 10:00–12:00 hours	611				
	3: 13:00–15:00 hours	400				
	4: 15:00–17:00 hours	508				
TCS	0: No coating apparent	205	0.60	0.07 (1.59, 2.07)	1.81	0.000
	1: Less than 1/3 of the area coated	1100				
	2: Between 1/3 and 2/3 of the area coated	563				
	3: More than 2/3 of the area coated	132				
Overall statistic						0.000

Pseudo-$R^2 = 0.1$.

OS, organoleptic score; TCS, tongue coating score; PI, plaque index; CI, calculus index; PD, pocket depths; mSBI, sulcus bleeding index; DT, decayed teeth; MT, missing teeth; FT, filled teeth; DMFT, decayed, missing and filled teeth.

(Van Steenberghe 1997). There is no equipment that can measure all the causal elements of halitosis. OS is considered less reliable and is used sparsely in an epidemiological survey, because of its limitations, such as influence from environmental conditions (noise or temperature). In the present study, however, relatively higher correlations were found between VSCs and OS. Greenman et al. (2004) also scored intensities of individual gases related to oral malodor. This may suggest that OS is applicable even in large-scale surveys as well as for examination and diagnosis in clinics, if appropriate calibration using T&T olfactometer™ is carried out.

The manufacturer of Halimeter® had not stated a definite value of ppb for normal reading for many years. Yaegaki & Sanada (1992b) recommended 75 ppb as a perceived level of malodor in mouth air. Miyazaki et al. (1995) also utilized the same standard in their survey of the general population for halitosis in Japanese. Recently, the manufacturer suggested 110 ppb or below as a normal reading in their instructions (http://www.halimeter.com/halcal.htm). To make this study more objective, we included both evaluation methods in our study.

Characteristics of VSC distribution

In the present study, the prevalence of halitosis was higher than that reported by previous epidemiological studies in Japan, which ranged from 6% to 23% (Miyazaki et al. 1995). This may be because of the overall poorer oral hygiene and periodontal status of the subjects in our study. The mean PI was 2.65%, and 94.5% of the subjects had gingivitis. Our results are similar to previous investigations in finding that age does not appear to contribute to the incidence of halitosis (Miyazaki et al. 1995, Söder et al. 2000), but they differ from previous studies (Sulser et al. 1939, Miyazaki et al. 1995) by showing a correlation between gender and VSCs with the logistic regression analysis. VSCs in mouth air have been found to be elevated in females during mid-cycle and around menstruation, as well as during the mid-proliferative and mid-luteal phases (Tonzetich et al. 1978). VSCs varied according to the assessment time, with the highest mean value being during the 10:00–12:00 hours period, and the lowest between 13:00 and 15:00 hours. The VSCs values decreased markedly after oral activities such as eating and drinking. This may be because oral activities tend to reduce the number of VSC-producing bacteria in the mouth by stimulating salivary flow, and because eating decreases oral pH, a factor that earlier studies have identified as inhibiting the production of malodor (McNamara et al. 1972, Quirynen et al. 2002).

Primary risk factors in halitosis

It has become increasingly clear that tongue coating is the factor in halitosis (Yaegaki & Sanada 1992a). We found a significant correlation between VSCs and TCS for all age groups, which was the same result as reported by Hinode et al. (2003). TCS also had the highest odds ratio value of all factors. The tongue coating is comprised of epithelial cells from the oral mucosa, microorganisms, and food debris, as well as microorganisms and leucocytes from periodontal pockets. The dorsal surface of the tongue is therefore the favorite site for growth of anaerobic bacteria responsible for halitosis (ÇiÇek et al. 2003). It has been demonstrated that cleaning the tongue reduces levels of VSCs, and removes microorganisms (Yaegaki & Sanada 1992a, Yaegaki et al. 2002, ÇiÇek et al. 2003).

Other factors influencing halitosis

Periodontal disease is regarded as another cause of halitosis (Yaegaki & Sanada 1992a, Miyazaki et al. 1995, Söder et al. 2000). We found relationships between VSCs and mSBI, CI and PD. Subjects with high mSBI or CI values were 1.18–1.41 times more likely to have elevated levels of VSCs. There is a high correlation between gingival crevicular fluid (GCF) volume and H_2S produced by the GCF (Rizzo 1967, Horowitz & Folke 1973). Increased VSCs are also positively correlated with the bleeding index because haemoglobin is required for the growth of *Porphyromonas gingivalis* (Yaegaki & Sanada 1992a). In addition, blood decomposition products themselves can also produce sulphur-containing peptides and amino acids that are the source of VSCs. Some studies (Persson et al. 1990, Awano et al. 2002, Nakano et al. 2002) have shown that periodontal pathogenic bacteria such as *Tannerella forsythia*, *P. gingivalis*, and *Prevotella intermedia*, influence the production of VSCs. Conversely, VSCs may damage periodontal tissues (Johnson et al. 1992).

We did not find any correlation between the PI and VSC values, which agrees with a previous report (Miyazaki et al. 1995). A recent investigation also showed decreasing level of VSCs in the absence of mechanical plaque control (Carvalho et al. 2004). Nor did we find correlation between VSCs and dental caries, which has also been reported by others (Miyazaki et al. 1995). However, it has been reported that young children with malodor were caries free, whereas age-matched children without malodor had moderate-to-high caries activity (Paryavi-Gholami et al. 1999). Glucose and sucrose can inhibit the enzyme activity of salivary peptides by creating an acidic environment (Tonzetich 1977, Kleinberg & Codipilly 1995, Greenman et al. 1996). Therefore, acidic conditions, such as those created by dental plaque, may suppress VSC production.

The smoking rate in this study population was very high. Tobacco smoke itself contains VSCs (Stedman 1968). Furthermore, the negative effect of smoking on periodontal tissues (Taybos 2003) may promote halitosis. Previous studies have found no relationship between VSCs concentration in mouth air and smoking (Miyazaki et al. 1995, Söder et al. 2000).

We found that VSCs concentration was not correlated with socioeconomic status, knowledge of oral health, frequency of dental visits, or other behavioural factors. Moreover, no difference was found between the subjects who had good oral hygiene habits and those who did not. Tooth brushing in the evening was only significant in the one-way analysis. Tooth brushing reduces the number of bacteria and fermentable substrates in the mouth (Yankell 1994, Haffajee et al. 2001), and evening brushing may inhibit the large increase of bacteria that occurs while sleeping.

Severe periodontal disease is one of the major oral health problems in developing countries, because of the shortage of dental manpower and the high demand for dental health services (Saparamadu 1984). Although periodontal disease is an important factor in halitosis, only a few of the subjects in this study visited dentists or physicians. Furthermore, few of them thought oral problems caused halitosis. If these people were provided adequate education concerning the causes of halitosis (i.e., tongue coating and periodontal disease) they might have been motivated to visit the dentist and receive periodontal treatment and oral hygiene instructions. In order to improve oral health, effective and pragmatic oral health promotion activities must be conducted in a community. For these reasons, instructions for the prevention of halitosis should be included in oral health promotion activities.

Conclusion

There was a high prevalence of halitosis in the Chinese population we studied. We found that the level of VSCs varied with gender and the time of day the tests were conducted. Age and area of residence did not influence VSCs levels. The most important factors involved oral aetiology. Tongue coating played the most significant role in production of VSCs, followed by periodontal status. However, DMFT, smoking, socioeconomic status, oral hygiene and other social factors did not contribute to the incidence of halitosis.

Acknowledgements

This research was supported in part by the Japan China Medical Association research fund. The authors deeply appreciate the assistance and cooperation of the Mi Yun Committee for Oral Health, the Huai Rou Committee for Oral Health, the Feng Tai Hospital, and the Yue Tan Community Health Service Center.

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Clinical Relevance

An epidemiological study was conducted in a stratified population sample from China relating halitosis to TCS, mSBI index and CI. The results showed that tongue coating and periodontal status were the most significant factors related with halitosis. Oral health promotion programs that improve oral health are recommended to reduce halitosis.