ORAL DISEASES

Oral Diseases (2010) 16, 702–706. doi:10.1111/j.1601-0825.2010.01685.x

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ORIGINAL ARTICLE

The association of periodontal disease with oral malodour in a Japanese population

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AIM: The purpose of this study was to evaluate the association between oral malodour and periodontal disease, and to determine the effect of periodontal therapy on oral malodour.

MATERIALS AND METHODS: Oral malodour parameters, including volatile sulphur compound (VCS) measurement, methyl mercaptan/hydrogen sulphide ratio by gas chromatography, organoleptic testing, tongue coating score, and periodontal parameters were evaluated in 823 patients complaining of oral malodour. Amongst these patients, 89 with oral pathogenic halitosis received tongue cleaning and periodontal therapy. Oral malodour and periodontal parameters were measured at baseline and after treatment.

RESULTS: Amongst 823 patients, 102 were diagnosed with gingivitis and 721 with periodontitis. VCS levels and periodontal parameters increased according to the severity of oral malodour. Organoleptic testing significantly correlated with periodontal probing depth and a percentage of periodontal pocket depth ≥4 mm (r = 0.40 and 0.39 respectively). There were significant correlations between methyl mercaptan/hydrogen sulphide ratio and periodontal parameters. Significant decrease in oral malodour and periodontal parameters in 89 patients with oral pathogenic halitosis was also observed after periodontal treatment.

CONCLUSIONS: Oral malodour is associated with periodontal disease, and periodontal therapy combined with tongue cleaning is beneficial for oral pathogenic halitosis.
Oral Diseases (2010) **16**, 702–706

Keywords: periodontal disease; periodontal therapy; oral malodour; volatile sulphur compounds

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Received 6 July 2009; revised 28 December 2009; accepted 20 January 2010

Introduction

Volatile sulphur compounds (VSCs), responsible for oral malodour, consist primarily of hydrogen sulphide (H_2S), methyl mercaptan (CH_3SH) and dimethyl sulphide [$(CH_3)_2SH$] (Tonzetich, 1971, 1977, 1978). These compounds are produced by putrefaction of glycoproteins and proteins by micro-organisms in the oral cavity, including the gingival sulcus, periodontal pockets, tongue dorsal surfaces and other mucous surfaces (Kleinberg and Westbay, 1990; Persson *et al*, 1990; Yaegaki and Sanada, 1992b; Rosenberg, 1996). Persson *et al* (1990) have reported that periodontal pathogens such as *Porphyromonas gingivalis*, *Prevotella intermedia*, *Tannerella forsythia* and *Treponema denticola* produce high levels of H_2S and CH_3SH. The proportion of these periodontal pathogens detected on the tongue has been reported to be significantly correlated with VSC levels or periodontal pocket depth (Tanaka *et al*, 2004). Furthermore, previous studies have indicated that VSCs in mouth air increase with the severity of periodontal disease (Tonzetich, 1978; Yaegaki and Sanada, 1992a,b). Furthermore, VSC levels are elevated in deep periodontal pockets compared with shallow periodontal pockets (Solis-Gaffar *et al*, 1980; Coli and Tonzetich, 1992; Morita and Wang, 2001a,b,c). These studies suggest that periodontal disease is one of the causes of oral malodour. By contrast, some studies have reported that periodontal parameters such as periodontal pocket depth, clinical attachment level and gingival index (GI) show no significant correlation with the degree of oral malodour (Bosy *et al*, 1994; Stamou *et al*, 2005). In these studies, however, portable devices were employed for measuring VSCs and a small number of subjects were enrolled, which might affect the evaluation of the association between periodontal disease and oral malodour.

The purpose of this study was to evaluate the association of oral malodour and periodontal disease using a gas chromatography in 823 Japanese patients, and to then subsequently determine the effect of periodontal therapy on oral pathogenic halitosis.

Materials and methods

Subjects

Between November 1997 and October 2007, 823 patients (282 men and 541 women) complaining of oral malodour visited the Oral Malodour Clinic at Kagoshima University Medical and Dental Hospital and were enrolled in this study. Informed consent was obtained from patients and permission for this study was obtained from the Ethical Committee of Kagoshima University Graduate School of Medical and Dental Sciences, Kagoshima, Japan. Patients with fewer than 12 teeth or under the age of 16 were excluded.

Oral malodour assessment

Patients were asked to refrain from eating, drinking, chewing, brushing, using mouth rinse, smoking and using scented cosmetics for 3 h before oral malodour assessment. Organoleptic testing (OLT) performed by the direct sniffing of expelled mouth air at a distance of approximately 10 cm from the nose of the evaluator was carried out by three dentists who were trained in this examination. Evaluation of the OLT was recorded as a score of 0–5 (0: absence of odour; 1: questionable odour, 2: slight malodour; 3: moderate malodour; 4: strong malodour, 5: severe malodour; Murata *et al*, 2002). Kappa value range between examiners was 0.44–0.55. VSC levels were analysed using a gas chromatography (GC-14B; Shimadzu, Kyoto, Japan) equipped with a flame photometric detector. Mouth air (5 ml) was aspirated with a gas-tight syringe. Samples were injected onto the gas chromatography column at 70°C. A Teflon™ column was packed with 5% polyphenylether 5 ring on 80–100 mesh Uniport HP (GL Sciences, Tokyo, Japan). The concentrations of H_2S, CH_3SH and $(CH_3)_2SH$ were determined with standard gas prepared with a permeater (PD-1B; Gastec Co., Kanagawa, Japan) containing a calibrated permeation tube (Gastec Co.). Yaegaki and Sanada (1992b) have revealed that the CH_3SH/H_2S ratio increases in patients with periodontal disease. In this study, measurement of CH_3SH/H_2S ratio by gas chromatography was evaluated in all patients. Tongue coating (TC) score was measured as a score of 0–4 (0: absence of tongue coating; 1: thin tongue coating covering 1/3 of tongue dorsum; 2: thin tongue coating covering 2/3 or thick tongue coating covering 1/3 of tongue dorsum; 3: thin tongue coating covering more than 2/3 or thick tongue coating covering 2/3 of tongue dorsum; 4: thick tongue coating covering more than 2/3 of tongue dorsum). TC score measurement was performed by three dentists. The Kappa value range between examiners was 0.56–0.58.

Periodontal examination

Periodontal probing depth (PPD) and bleeding on probing (BoP) were assessed using a Williams probe at six points on all teeth. Moreover, periodontal status was determined as a percentage of teeth characterized by PPD of 4 mm or more (PPD%). GI (Loe, 1967) was used for the determination of gingival inflammation. Plaque index (PlI) modified by Turesky–Gilmore–Glickman (Turesky *et al*, 1970) was used for the determination of adherent dental plaque. Patients were diagnosed as healthy or having periodontal disease based on periodontal examination and/or full-mouth radiographs.

Diagnosis of oral malodour

In addition to oral malodour assessment and periodontal examination, a direct interview using a questionnaire was also used for diagnosis. Patients were diagnosed according to the clinical classification developed by Yaegaki and Coil (2000). The degree of oral malodour was evaluated by OLT score.

Oral malodour and periodontal treatment

All patients were treated for halitosis using guidelines proposed by Yaegaki and Coil (2000). In total, 102 patients had gingivitis and 721 patients had periodontitis. Amongst these patients, 89 with oral pathogenic halitosis received tongue cleaning with a tongue brush (Tongue Mate™; Dent-Care, Osaka, Japan), and underwent periodontal treatment consisting of oral hygiene instruction, scaling and root planning or periodontal surgery. Tongue cleaning was performed to clean the posterior tongue following the protocol described by Yaegaki *et al* (2002). Patients were instructed so that tongue brushes could be moved from the terminal sulcus to the front of the tongue, to avoid brushing the tonsil and causing infection of the respiratory system. VSC levels, OLT scores, TC scores and periodontal parameters were measured 1–2 weeks before the treatment and 1–3 months after the treatment.

Statistical analysis

Data were expressed as mean ± standard deviation. Association of oral malodour and periodontal parameters at baseline was analysed using one-way analysis of variance (ANOVA) with *post hoc* Scheffe's multiple comparison. The correlation analysis between oral malodour and periodontal parameters at baseline was determined using Pearson's correlation. Changes in oral malodour and periodontal parameters after treatment were statistically evaluated using a Student's paired *t*-test.

Results

Analysis of oral malodour and periodontal parameters

As the degree of oral malodour became more severe, TC score, H_2S, CH_3SH, $(CH_3)_2SH$, total VSC level, CH_3SH/H_2S ratio and periodontal parameters significantly increased (Table 1). When the patients were classified based on halitosis diagnosis, the population of oral pathogenic halitosis was highest (44.7%), followed by pseudo-halitosis (31.2%), physiological halitosis (16.9%), extraoral pathogenic halitosis (4.7%) and halitophobia (2.4%). The findings, therefore, reveal that 66.3% of the population had genuine halitosis (physiological, oral pathogenic and extra oral pathogenic halitosis). Table 2 shows Pearson's correlation coefficients between clinical parameters. There were

Table 1 Relationship between oral malodour and periodontal parameters at baseline (classified by degree of oral malodour)

	Absence of odour or questionable odour	*Slight malodour*	*Moderate malodour*	*Strong or severe malodour*	*Total, N (%)*
Women	126	207	180	28	541 (65.7)
Men	45	97	101	39	282 (34.3)
Total	171	304	281	67	823 (100.0)
Age (years)	41.68 ± 12.67	45.12 ± 14.13	49.16 ± 13.36[ab]	51.48 ± 12.18[ab]	46.30 ± 13.77
Number of teeth	25.77 ± 4.49	25.03 ± 5.12	24.43 ± 5.64	24.24 ± 5.35	24.91 ± 5.22
TC score	1.59 ± 0.72	2.23 ± 0.64[a]	2.76 ± 0.62[ab]	3.11 ± 0.62[abc]	2.35 ± 0.81
H_2S (ppb)	58.76 ± 72.72	155.17 ± 214.98	452.12 ± 575.99[ab]	1017.43 ± 1089.02[abc]	306.72 ± 544.10
CH_3SH (ppb)	16.64 ± 22.09	64.33 ± 89.24	212.36 ± 321.88[ab]	627.07 ± 703.83[abc]	150.78 ± 323.11
$(CH_3)_2S$ (ppb)	22.34 ± 19.31	35.88 ± 27.99[a]	57.58 ± 47.96[ab]	112.58 ± 109.12[abc]	46.72 ± 51.64
VSCs (ppb)	97.73 ± 96.61	255.38 ± 293.59	722.07 ± 878.77[ab]	1757.08 ± 1738.65[abc]	504.22 ± 860.76
CH_3SH/H_2S	0.35 ± 0.38	0.52 ± 0.46	0.66 ± 0.77[a]	0.96 ± 1.17[abc]	0.57 ± 0.67
PPD	2.40 ± 0.38	2.53 ± 0.44	2.80 ± 0.66[ab]	3.19 ± 0.83[abc]	2.65 ± 0.60
PPD%	5.74 ± 8.18	8.15 ± 10.39	15.24 ± 16.58[ab]	24.03 ± 19.53[abc]	11.36 ± 14.37
BoP (%)	16.74 ± 14.54	23.10 ± 18.89[a]	32.10 ± 22.95[ab]	44.44 ± 28.49[abc]	26.59 ± 21.93
GI	1.03 ± 0.37	1.10 ± 0.43	1.32 ± 0.43[ab]	1.51 ± 0.39[abc]	1.20 ± 0.44
PlI	1.71 ± 0.70	1.87 ± 0.76	2.27 ± 0.79[ab]	2.52 ± 0.92[ab]	2.03 ± 0.81

Values represent mean ± standard deviation. The degree of oral malodour was classified by the results of the organoleptic test: 0: absence of odour; 1: questionable odour, 2: slight malodour; 3: moderate malodour; 4: strong malodour, 5: severe malodour. CH_3SH/H_2S: CH_3SH/H_2S ratio by gas chromatography measurement.
[a]Significant difference compared with absence of odour or questionable odour ($P < 0.05$).
[b]Significant difference compared with slight malodour ($P < 0.05$).
[c]Significant difference compared with moderate malodour ($P < 0.05$).
TC, tongue coating; VSC, volatile sulphur compound; PPD, periodontal probing depth; BoP, bleeding on probing; GI, gingival index; PlI, plaque index.

Table 2 Correlation analysis between oral malodour and periodontal parameters at baseline ($n = 823$)

	OLT score	*TC score*	*H_2S*	*CH_3SH*	*$(CH_3)_2S$*	*VSCs*	*CH_3SH/H_2S*	*PPD*	*PPD%*	*BoP (%)*	*GI*	*PlI*
OLT score	1.00	0.61**	0.46**	0.46**	0.44**	0.49**	0.25**	0.40**	0.39**	0.39**	0.36**	0.36**
TC score		1.00	0.28**	0.27**	0.22**	0.29**	0.16**	0.24**	0.22**	0.22**	0.22**	0.26**
H_2S			1.00	0.78**	0.67**	0.97**	−0.06	0.24**	0.23**	0.22**	0.19**	0.22**
CH_3SH				1.00	0.78**	0.92**	0.21**	0.30**	0.29**	0.30**	0.26**	0.21**
$CH_3)_2S$					1.00	0.78**	0.22**	0.26**	0.24**	0.26**	0.24**	0.19**
VSCs						1.00	0.05	0.28**	0.27**	0.27**	0.23**	0.23**
CH_3SH/H_2S							1.00	0.18**	0.17**	0.20**	0.18**	0.10**
PPD								1.00	0.91**	0.64**	0.61**	0.43**
PPD%									1.00	0.63**	0.56**	0.43**
BoP (%)										1.00	0.76**	0.46**
GI											1.00	0.51**
PlI												1.00

OLT, organoleptic testing; TC, tongue coating; VSC, volatile sulphur compound; PPD, periodontal probing depth; BoP, bleeding on probing; GI, gingival index; PlI, plaque index.
**$P < 0.01$.

significant correlations between oral malodour parameters and periodontal parameters. In addition, CH_3SH/H_2S ratio significantly correlated with PPD and PPD% at baseline ($r = 0.18$ and 0.17 respectively).

The effect of periodontal therapy on oral pathogenic halitosis

A total of 89 patients with oral pathogenic halitosis received tongue cleaning and periodontal treatment. The number of patients who received oral hygiene instructions including plaque control and scaling on the supra gingiva, scaling and root planning and periodontal surgery were 35, 47 and 7 respectively. Table 3 shows oral malodour and periodontal parameters in oral pathogenic halitosis patients at baseline and after periodontal treatment. Significant decreases in all parameters were observed following treatment. Changes in VSC concentration in mouth air were determined. CH_3SH, H_2S and $(CH3)_2S$ levels decreased by 87.9%, 78.6% and 61.9% respectively and CH_3SH/H_2S ratio significantly decreased after treatment. The decrease in mean OLT scores, VSC levels, PPD and PPD% in the groups receiving oral hygiene instructions, scaling and root planning or periodontal surgery was as follows: 1.2, 988.0 ppb, 0.4 mm and 7.1% in the oral hygiene instructions group; 1.4, 743.3 ppb, 0.9 mm and 20.0% in scaling and root planning; 1.8, 1480.5 ppb, 0.9 mm and 17.7% in the periodontal surgery group.

Discussion

Many studies have revealed the association between periodontal disease and oral malodour. VSC levels in mouth air have been shown to increase with an increase

Table 3 Changes in oral malodour and periodontal parameters at baseline and after periodontal therapy in patients with oral pathogenic halitosis

	Baseline	*After treatment*
Women	54	–
Men	35	–
Total	89	–
Age (years)	50.40 ± 13.21	–
Number of teeth	24.39 ± 5.40	23.93 ± 5.78**
OLT score	3.41 ± 0.57	2.09 ± 0.73**
TC score	2.82 ± 0.62	1.87 ± 0.78**
H_2S (ppb)	654.60 ± 813.51	139.77 ± 245.93**
CH_3SH (ppb)	380.19 ± 624.92	46.02 ± 81.42**
$(CH_3)_2S$ (ppb)	78.31 ± 85.96	29.82 ± 21.39**
VSCs (ppb)	1113.11 ± 1431.00	215.60 ± 319.01**
CH_3SH/H_2S	0.74 ± 0.75	0.47 ± 0.57**
PPD	3.10 ± 0.68	2.41 ± 0.43**
PPD%	22.22 ± 17.53	7.47 ± 10.04**
BoP (%)	44.79 ± 25.43	13.09 ± 11.79**
GI	1.52 ± 0.35	0.89 ± 0.38**
PlI	2.38 ± 0.78	0.92 ± 0.49**

Values represent mean ± standard deviation. OLT, organoleptic testing; TC, tongue coating; VSC, volatile sulphur compound; PPD, periodontal probing depth; BoP, bleeding on probing; GI, gingival index; PlI, plaque index; CH_3SH/H_2S, CH_3SH/H_2S ratio by measurement with gas chromatography.
**$P < 0.01$.

in the number and depth of periodontal pockets (Tonzetich, 1978). Yaegaki and Sanada (1992a,b) have demonstrated that the concentrations of H_2S and CH_3SH in mouth air are higher in patients with periodontal disease with a probing depth >4 mm than those in healthy subjects. Furthermore, periodontal pathogens produce significantly higher amounts of sulphides than other bacteria (Persson *et al*, 1990). In this study, we examined clinical parameters in 823 patients complaining of oral malodour to clarify any association between periodontal disease and oral malodour. As a result, periodontal parameters and VSC levels significantly increased according to the severity of oral malodour (Table 1), and periodontal parameters showed significant correlations with OLT and VSC levels (Table 2). Moreover, oral malodour parameters significantly decreased after periodontal treatment (Table 3). From these results, we suggest that oral malodour is associated with periodontal disease. However, some studies have demonstrated that oral malodour is not associated with periodontal status. Bosy *et al* (1994) have reported that the mean number of periodontal pockets ≥5 mm and ≥7 mm does not correlate with OLT score and VSC levels in 127 subjects. Stamou *et al* (2005) have also reported that probing pocket depth has no correlation with oral malodour parameters in 71 Israelis. These studies employed portable sulphide monitors for measuring VSC levels. Murata *et al* (2002) have shown that sulphide monitors such as Halimeter™ (Interscan Co., Chatsworth, CA, USA), which are widely used for oral malodour measurement, detect volatile substances other than H_2S, CH_3SH and $(CH_3)_2SH$, and that gas chromatography should be considered the gold standard for VSC measurement. In this study, we measured VSC levels using a gas chromatography equipped with a flame photometric detector, and measured PPD at six points on all teeth. Periodontal status was estimated by mean PPD and the percentage of PPD ≥4 mm. Furthermore, a large number of subjects ($n = 823$) were enrolled in this study, increasing the strength and credibility of the data presented. The differences in the devices measuring VSC, periodontal examination design and the subject number may affect the differences observed from previous studies in the correlations between periodontal disease and oral malodour.

In this study, there were significant correlations between OLT score and VSC levels ($r = 0.49$). Niles and Guffar (1997), who measured VSC levels by gas chromatography using a six-port valve auto-injection system and a Teflon column, have reported high correlations, $r = 0.78$ between OLT score and VSC levels. By contrast, we also utilized gas chromatography for detection of VSC levels, but we employed a sample injection system using a gas-tight syringe and Teflon column. Murata *et al* (2002) have indicated that if a gas-tight syringe is used for sampling and injection onto a gas chromatograph, a huge back pressure of carrier gas has access into the syringe, and as a result, the dead space in the gas-tight syringe is increased by the high back pressure. Furthermore, most reports, including this study, did not allow their subjects to eat and drink for 2–3 h prior to the oral malodour measurement. A recent study reported that VSCs increase constantly for 5 h after eating and oral cleaning (Fukui *et al*, 2008). These factors, therefore, might cause a lower correlation between OLT score and VSC levels in this study. CH_3SH/H_2S ratio was employed for determination of association between oral malodour and periodontal disease because it has been reported that CH_3SH/H_2S ratio increases in patients with periodontal disease (Yaegaki and Sanada, 1992b). CH_3SH/H_2S ratio increased as the degree of oral malodour became more severe (Table 1), and was significantly correlated with periodontal parameters (Table 2). Moreover, CH_3SH/H_2S ratio significantly decreased after periodontal treatment (Table 3). These results suggest that CH_3SH/H_2S ratio is effective for diagnosis of oral malodour and evaluation of the outcome of treatment for oral malodour associated with periodontal disease.

As patients with oral pathogenic halitosis received both tongue cleaning and periodontal treatment in this study, it is difficult to evaluate to what extent periodontal treatment alone was effective in decreasing oral malodour. However, Yaegaki and Sanada (1992a,b) have indicated that patients with periodontal disease have increased TC than healthy controls. In this study, TC score significantly correlated with periodontal parameters. Thus, the existence of periodontal disease may be associated with an adherence of TC. Therefore, we suggest that periodontal treatment is a valuable causal therapy in oral pathogenic halitosis.

In conclusion, we suggest that oral malodour is associated with periodontal status and that periodontal

treatment combined with tongue brushing is effective for oral pathogenic halitosis therapy. Furthermore, the CH_3SH/H_2S ratio may be useful for the diagnosis of oral malodour and for the assessment of oral malodour treatment.

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