Journal of Clinical Periodontology
Official Journal of The European Federation of Periodontology
Founded by the British, Dutch, French, German, Scandinavian, and Swiss Societies of Periodontology

J Clin Periodontol 2009; 36: 964–969 doi: 10.1111/j.1600-051X.2009.01473.x

Journal of Clinical Periodontology

Clinical reliability of non-organoleptic oral malodour measurements

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Vandekerckhove B, Van den Velde S, De Smit M, Dadamio J, Teughels W, Van Tornout M, Quirynen M. Clinical reliability of non-organoleptic oral malodour measurements. J Clin Periodontol 2009; 36: 964–969. doi: 10.1111/j.1600-051X.2009.01473.x.

Abstract

Aim: Measurement of volatile sulphur compounds (VSC) by portable sulphur monitors (Halimeter®, OralChroma™) is a common practice for diagnosis of oral malodour. In this study, the clinical value of these devices was examined.

Materials and Methods: Two hundred and eighty patients with bad breath complaints attending a halitosis consultation were enrolled. Organoleptic scores were given by a trained and calibrated judge, before measurement of the VSC levels (Halimeter®, OralChroma™), to avoid any bias.

Results: Significant correlations were found between the organoleptic assessment, the Halimeter®, and the OralChroma™ ($R = 0.74$ for organoleptic *versus* Halimeter®; 0.66 for organoleptic *versus* OralChroma™; 0.63 for Halimeter® *versus* OralChroma™). The sensitivity and specificity (with regard to the organoleptic score) to detect patients with/without oral malodour for the Halimeter® were 63% and 98%, respectively, and for the OralChroma™ 69% and 100% when using the cutoffs suggested by the manufacturer. By lowering these values, sensitivity could be improved without a significant decrease in specificity (both devices).

Conclusions: We concluded that the measurement of the VSC levels can be used as an adjunct to the organoleptic assessment. Thresholds should be revisited in order to improve their clinical utility. These devices can prove the absence of malodour in case of pseudo-halitosis.

Key words: oral malodour; organoleptic assessment; portable sulphur monitors; threshold levels

Accepted for publication 2 July 2009

Halitosis is a general term used to define an unpleasant odour emanating from the breath and can be of oral or non-oral origin. In approximately 80–90% of all cases, bad breath is caused by oral conditions, defined as oral malodour (Miyazaki et al. 1995, Delanghe et al. 1997, Quirynen et al. unpublished data). Non-oral causes of genuine halitosis may include disturbances of the upper and lower respiratory tract, disorders of the gastrointestinal tract, some systemic diseases, metabolic disorders and carcinomas (Preti et al. 1995, Delanghe et al. 1997, Tangerman 2002, Porter & Scully 2006). A number of the self-referred cases consist of subjects with the so-called ''pseudo-halitosis'', in whom no objective signs of malodour can be determined, but who are complaining of continuous bad breath. If after diagnosis of pseudo-halitosis, the patient still believes that there is bad breath, one can speak about halitophobia (Yaegaki & Coil 2000, Seemann et al. 2006).

Oral malodour is the result of the degradation of organic substrates by anaerobic bacteria, thereby producing a range of malodorous molecular components of which the volatile sulphur compounds (VSCs) are the most extensively studied. In particular, hydrogen sulphide (H_2S), methyl mercaptan (CH_3SH) and dimethyl sulphide [$(CH_3)_2S$] have demonstrated to contribute to oral malodour (Tonzetich 1977). In addition to the VSCs, other compounds like indole, skatole, cadaverine, putrescine and short-chain fatty acids may also play a role in certain conditions (Goldberg et al. 1994, Loesche & Kazor 2002).

Until today, an organoleptic assessment is still the gold standard for diagnosis of bad breath (Greenman & Rosenberg 2005). It is easy to perform and requires no extra apparatus. However, the evaluation clearly also has a degree of subjectivity and training and

Conflict of interest and source of funding statement

No potential conflicts of interest and no sources of funding.

calibration is necessary to improve the objectivity and reproducibility within and between examiners.

Gas chromatography is probably the most reliable, objective and reproducible method for the measurement of the VSCs (Murata et al. 2002). However, it is expensive, not portable and needs trained personnel, which makes it unsuitable for routine analysis (Furne et al. 2002). In order to overcome these practical drawbacks, portable sulphur monitors (Halimeter®) measuring the total concentration of sulphur compounds, and portable gas chromatographs (OralChroma™) determining the concentrations of the three most important VSCs, were developed. In this article, the clinical value of these devices and the threshold levels proposed by the respective companies were investigated using the results of a group of 280 patients.

Materials and Methods

Subject selection

Two hundred and eighty patients (152 females, mean age 40) complaining of halitosis and attending the multidisciplinary breath odour clinic (University Hospitals of the Catholic University of Leuven, Belgium) were consecutively enrolled. Twenty-six of them were smokers. Patients with an extra-oral cause of halitosis were excluded. All patients confirmed that they were not suffering from any disease and did not receive medical treatment (especially no antibiotics and/or periodontal therapy) within 2 months before measurements. Patients with signs of pharyngitis or acute/chronic tonsillitis were also excluded. One hundred and twenty-one patients had a tongue coating as the only cause of bad breath. Periodontitis and gingivitis were diagnosed as main causes of halitosis in 30 and 6 subjects, respectively. A combination of tongue coating and periodontitis/gingivitis was found in 50 patients and 13 subjects showed a dry mouth in combination with a tongue coating or periodontitis/gingivitis. In 60 patients, no objective signs of halitosis could be found (pseudo-halitosis).

All patients received a letter with instructions before the examinations. Two days before their appointment, they had to avoid the intake of garlic, onions and spicy food. Twelve hours before the measurements, they also had to refrain from alcohol or coffee, and from smoking. On the morning of the appointment, it was forbidden to use chewing gums, mints, drops, scents and mouth rinses. On the other hand, they could perform normal oral hygiene (tooth brushing) and have breakfast. All measurements were recorded between 8:30 and 11:30 hours (before lunch) and at least 2 h after eating or drinking and oral hygiene.

Clinical examination

The oral cavity was examined, paying attention to caries, the level of oral hygiene (plaque accumulation, gingival inflammation), periodontal pockets (using a manual periodontal probe), removable appliances, dry mouth and tongue coating. The latter was scored by visual inspection from 0 to 3 with 0 = no coating, 1 = thin coating on 1/3 of the tongue, 2 = thin coating on more than 1/3 of the tongue or thick coating on only 1/3 of the tongue and 3 = thick coating on more than 1/3 of the tongue.

Organoleptic assessment

The organoleptic score was determined by a trained and calibrated judge who tested her ability to distinguish odours using the Smell Identification Test® (Sensonics Inc., Haddon Heights, NJ, USA) and to detect odours at low concentrations, using a series of dilutions of the following substances: skatole, putrescine, isovaleric acid and dimethyl disulphide (Doty et al. 1984). A 0–5 score was given where 0 represented absence of odour, 1 was given for barely noticeable odour, 2 for slight malodour, 3 for moderate malodour, 4 for strong malodour and 5 for extremely foul malodour. Breath was scored as described by Rosenberg at rest (open mouth without breathing) and when the patients counted from 1 to 11 (Rosenberg 1996). The last score has been used for the statistics. The judge also smelled nasal breath (when the subjects exhaled through the nose while keeping their mouth closed) in order to exclude extra-oral causes, and a sample of the tongue coating was removed by means of a periodontal curette and scored as well. The organoleptic score preceded all other measurements to avoid any bias.

Measurement of sulphur compounds

The global concentration of sulphur-containing compounds was measured using a portable sulphur monitor (Halimeter®, Interscan corporation, Chatsworth, CA, USA) as previously described (Rosenberg et al. 1991a). The detector was zeroed on ambient air. Oral air samples were taken using a straw, which was connected to the inlet of the device. Patients closed their mouth for 30 s before the procedure and held their breath during the sampling. The straw was inserted approximately 3 cm in the nearly closed mouth and the subjects did not touch the straw.

Next to the Halimeter®, a portable gas chromatograph (OralChroma™, Abilit Corporation, Osaka City, Japan) was used, which measures the concentration of H_2S, CH_3SH and $(CH_3)_2S$. Sample collection occurred by use of a disposable syringe (all-plastic syringes, 1 ml), which was inserted into the oral cavity of the volunteers. Subjects had to close their mouth for 30 s before sample collection. 0.5 ml of mouth air was then injected into the measuring device. After 8 min., the process was completed and the concentration of the three gases were displayed in either ng/10 ml or ppbv (nmol/mol).

Statistical analysis

Statistical analysis was carried out using STATISTICA (Statsoft Benelux NV, Groningen, the Netherlands). Correlations were determined using the Spearman correlation coefficient. A regression with forward variable selection using the Aikaike's information criterion was used to find the multiple regression model with the highest explanatory power.

Results

General results

From the 280 patients enrolled (Fig. 1), 63 showed an organoleptic score 0 (22.5%), 57 score 1 (20.4%), 73 score 2 (26.1%), 55 score 3 (19.6%), 29 score 4 (10.4%) and 3 score 5 (1.1%). The mean Halimeter® value was 228 (SD: 229) with a large variability (Fig. 1). The average scores for H_2S, CH_3SH and $(CH_3)_2S$ measured with the OralChroma™ were 147 (SD: 280), 117 (SD: 232) and 45 ppb (SD: 141), respectively, and again a large variability could be observed (Fig. 1). The mean sum of these three gases was 308 ppb (SD: 481).

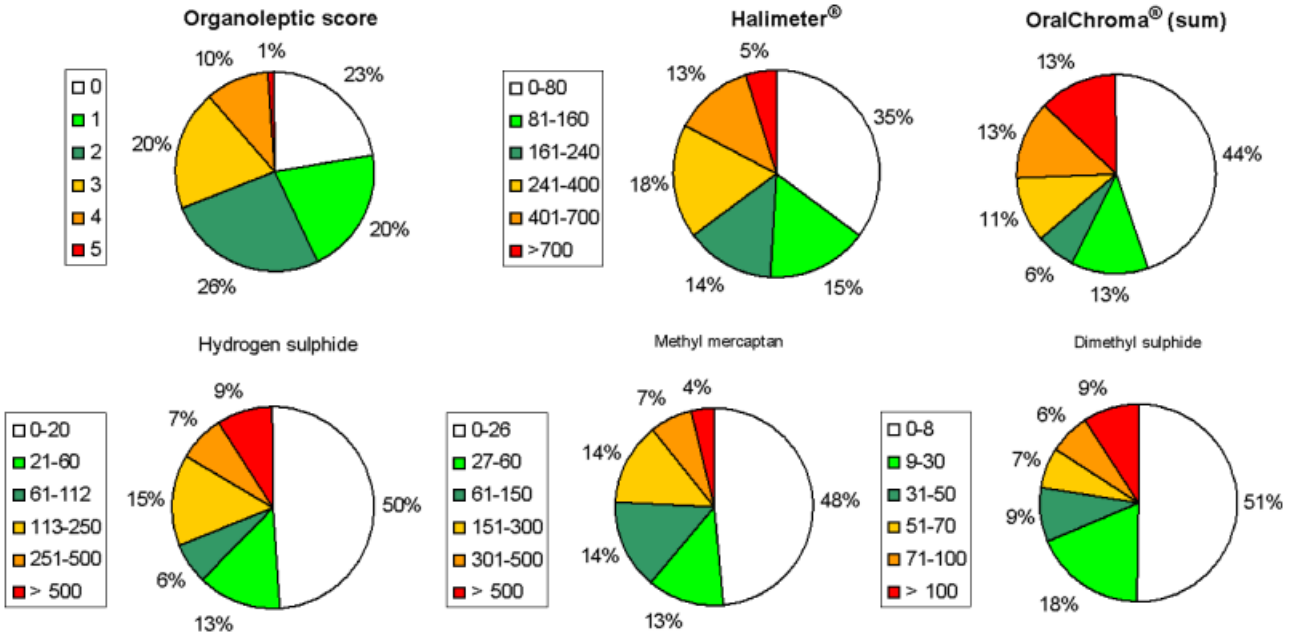

Fig. 1. Organoleptic scores and volatile sulphur compounds levels (in ppb).

Correlations between the different assessments

Significant correlations were found between the organoleptic assessment, the Halimeter® values and the OralChroma™ levels of H_2S, CH_3SH and $(CH_3)_2S$ (Table 1/Fig. 2). Correlation with the organoleptic score was slightly higher for the Halimeter® than for the OralChroma™ (Table 1).

The organoleptic assessment, the Halimeter® values and the OralChroma™ levels were also significantly correlated with the amount of tongue coating, the pocket probing depth and the level of oral hygiene. The best correlations were observed for the amount of tongue coating (Table 1).

Table 1. Correlations between the different parameters

	OLS	Hali	OC	H_2S	CH_3SH	$(CH_3)_2S$	TC	PPD	OHL
OLS	–	0.74†	0.66†	0.59†	0.61†	0.19	0.67†	0.43†	0.43†
Hali	–	–	0.63†	0.59†	0.58†	0.25†	0.63†	0.39†	0.40†
OC	–	–	–	0.82†	0.86†	0.45†	0.53†	0.34†	0.36†
H_2S	–	–	–	–	0.76†	0.14	0.43†	0.26†	0.35†
CH_3SH	–	–	–	–	–	0.28†	0.50†	0.34†	0.28†
$(CH_3)_2S$	–	–	–	–	–	–	0.25†	0.03	0.04

Values: Spearman's correlation coefficient (*R*).
OLS, organoleptic score; Hali, Halimeter®; OC, OralChroma™ (sum of H_2S, CH_3SH and $(CH_3)_2S$); TC, tongue coating; PPD, pocket probing depth; OHL, oral hygiene level.
H_2S, CH_3SH, $(CH_3)_2S$: measured by the OralChroma™.
†$p < 0.01$ (after Bonferroni).

Regression with forward variable selection

Halimeter® values, OralChroma™ levels of H_2S, CH_3SH, and $(CH_3)_2S$, oral hygiene index, tongue coating scores and pocket probing depth were considered for the regression analysis.

The forward selection resulted in a regression model containing the variables, in the order of addition to the model (in other words in the order of importance): tongue coating (TC), pocket probing depth (PPD), Halimeter® values (Hali), OralChroma™ levels of H_2S (H_2S) and level of oral hygiene (OH). The other variables [OralChroma™ levels of CH_3SH, and $(CH_3)_2S$] did not improve the model.

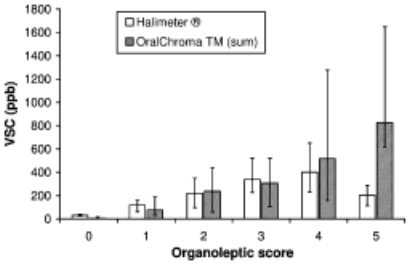

Fig. 2. Volatile sulphur compounds levels (Halimeter® and OralChroma™) according to the organoleptic score. Boxes: median; Whiskers: 25% and 75% percentiles

Based on this analysis, one could create the following formula (estimating the amount each variable contributes to the explanation of the organoleptic score, after other variables have been added)

$$\textbf{Organoleptic score} = -0.1984 + 0.6464\textbf{TC} + 0.1189\,\textbf{PPD} + 0.0012\textbf{Hali} + 0.0008\textbf{H}_2\textbf{S} + 0.1195\textbf{OHL}.$$

Sensitivity and specificity of the Halimeter® and the OralChroma™

According to the manufacturer, one can speak of oral malodour when VSC levels exceed 160 ppb for the Halimeter®. For the OralChroma™, this is the case when levels of H_2S or CH_3SH pass 112 ppb and 26 ppb, respectively. If only a 0 score is interpreted as no halitosis (and thus, 1–5 as halitosis), 71.7% of all subjects were classified correctly by the Halimeter® and

Table 2. Sensitivity, specificity, PPV and NPV for both devices (with different definition for halitosis)

Halitosis criteria	Halitosis if OLS $\geqslant 1$		Halitosis if OLS ≥ 2	
device	Halimeter®	OralChroma™	Halimeter®	OralChroma™
Sensitivity (%)	63.6	69.0	76.3	75.0
Specificity (%)	98.4	100.0	94.2	75.0
PPV (%)	99.3	100.0	94.6	80.0
NPV (%)	44.0	48.1	74.8	69.2

OLS, organoleptic score; PPV, positive predictive values; NPV, negative predictive values.

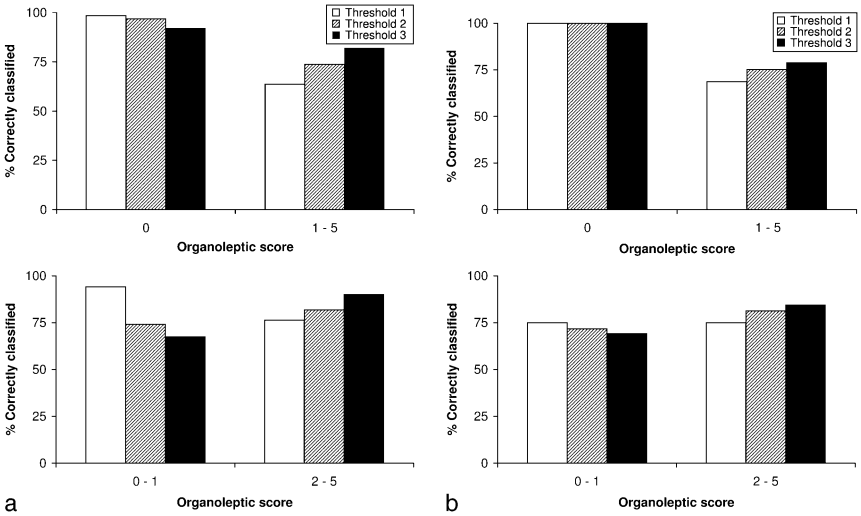

Fig. 3. (a) Percentage of patients correctly classified by the Halimeter® for both definitions of halitosis. Threshold 1: 160 ppb (proposed by the manufacturer: http://www.halimeter.com/halcal.htm). Threshold 2: 107 ppb (two-thirds of the proposed threshold). Threshold 3: 80 ppb (half of the proposed threshold). (b) Percentage of patients correctly classified by the OralChroma™ for both definitions of halitosis. Threshold 1: $H_2S > 112$ ppb or $CH_3SH > 26$ ppb (according to the manufacturers's instruction). Threshold 2: $H_2S > 75$ ppb or $CH_3SH > 17$ ppb (two-thirds of the proposed threshold). Threshold 3: $H_2S > 56$ ppb or $CH_3SH > 13$ ppb (half of the proposed threshold).

76.1% by the OralChroma™. If, however, scores 0 and 1 are considered as no halitosis (suggested by, e.g., Murata et al. 2002) and the rest as halitosis, the percentage of patients correctly classified by the Halimeter® and by the OralChroma™ was 83.9% and 75%, respectively.

The sensitivity, specificity and positive and negative predictive values (PPV and NPV) of both Halimeter® and OralChroma™, with regard to the organoleptic score to detect patients with and without oral malodour are summarized in Table 2 (for both definitions of halitosis).

In an attempt to improve the sensitivity, the calculations were repeated for lower threshold values than proposed by the manufacturer. Two new values (two-thirds and half of the proposed thresholds) were examined for each device. The percentage of patients correctly classified, by the two devices, using the original and new thresholds are shown in Fig. 3.

When using thresholds half of the proposed ones, and considering only an organoleptic score of zero as no halitosis, the sensitivity increased strongly to 81.6% and 78.3% for the Halimeter® and the OralChroma™, respectively. The specificity decreased $<5\%$ points for the Halimeter® (93.7%) or remained the same for the OralChroma™ (100%).

If the criterion from Murata and colleagues is used, the same improvement in the sensitivity is observed (90% for the Halimeter® and 84.4% for the OralChroma™), together with a big drop in the specificity (67.5% and 70% for Halimeter® and OralChroma™, respectively).

Discussion

As proven in the past, self-assessment of oral malodour is notoriously unreliable (Rosenberg et al. 1995). Therefore, other methods such as the organoleptic assessment and the measurement of VSCs have been proposed and are now common practices for diagnosis of bad breath. In this study, a comparison was made between these different measurements on a group of 280 patients attending a multidisciplinary breath odour clinic.

Until today, an organoleptic assessment is still the ''gold standard'' for diagnosis of breath malodour. The method is easy to perform, requires no extra apparatus and gives a reflection of the everyday situation when halitosis is detected. Moreover, the human nose can record more than 10,000 different odours (Hatt 2004). However, this method also has some important drawbacks. One of the most important disadvantages is that the assessment clearly has a certain degree of subjectivity. In order to improve the reliability and reproducibility, it is therefore best to use trained and calibrated judges who have tested their ability to smell both qualitatively as well as quantitatively (Doty et al. 1984, Rosenberg et al. 1991a, Yaegaki & Coil 2000, Nachnani et al. 2005).

In an attempt to obtain a more objective evaluation of the bad breath, relatively inexpensive portable sulphur detectors like the Halimeter® and the OralChroma™ were developed. Several studies, including this large-scale one, have shown good correlations between the organoleptic assessment and the Halimeter® ($R = 0.74$ in this study, 0.60 in Rosenberg et al. 1991a, b; 0.81 in Shimura et al. 1996 and 0.66 in Oho et al. 2001). Differences in correlation coefficients may be explained by variability in patient groups (inclusion criteria) and study conduct [the equipment used (calibration) and the organoleptic method (calibration of judges, number of judges, etc.)]. Although the Halimeter® lacks perfect accuracy, it provides useful data when calibrated at regular times (Furne et al. 2002). Limitations of the Halimeter® are that it cannot discriminate among the sulphur gases and that the sensitivity is lower for CH_3SH (the most odorous molecule) than for H_2S (Table 1). The latter might be a reason for the rather low VSC levels found with the Halimeter® for the three patients with an organoleptic score 5 in the population used in this study (Fig. 2). All three patients showed high OralChroma™ values for CH_3SH.

We have found a slightly lower correlation (than for the Halimeter®) between

the OralChroma™ values and the organoleptic score ($R = 0.66$). A recent publication has shown that sometimes the concentrations given by the software of the apparatus for the different VSCs are incorrect due to a wrong assignment of the place of the VSCs in the chromatogram. Therefore, the authors suggested to connect the device to a computer and to use the peak heights measured by hand to calculate the concentrations (Tangerman & Winkel 2008). This would make the analysis, however, less suitable for chairside use.

A comparable correlation was also found between the three individual VSCs measured by the OralChroma™ and the organoleptic score, which is consistent with gas chromatographic studies (Hunter et al. 2005). In our study, although the correlation for H_2S was only slightly lower, the strongest correlation was found for CH_3SH (the most odorous molecule with the lowest odour threshold), which was also seen in previous investigations (Awano et al. 2004). $(CH_3)_2S$ showed the weakest correlation confirming its limited role in oral malodour. Recent findings suggested that this compound is more associated with extra-oral causes of halitosis (Tangerman & Winkel 2007). The main advantage of the OralChroma™ is therefore that it can make a distinction among different sulphur gases, which can be helpful for a differential diagnosis.

When an organoleptic score above zero is interpreted as a diagnosis of halitosis, the sensitivity, specificity and the positive and negative predictive values of the Halimeter® and the OralChroma™ for detecting patients with and without oral malodour, were in the same range, although the ones for the OralChroma™ were slightly better. In a previous study with the same approach, similar values for the sensitivity and specificity of the Halimeter® (respectively, 61.1% and 87.8%) were found, but the positive and negative predictive values were lower (72%) and higher (81.5%), respectively, than in our observations (Baharvand et al. 2008). The reason for this discrepancy might be that the Baharvand study had a smaller patient group (77 patients) among them a large number of university students who had no oral malodour.

Our results indicate that patients who do not suffer from bad breath are correctly classified both by the Halimeter® and the OralChroma™ (high specificity). Moreover, when the threshold levels are attained by one of the two devices, oral malodour can also be organoleptically perceived (high PPV). The sulphur monitors can therefore be used efficiently to prove that there is no objectionable malodour in case of pseudo-halitosis or halitophobia. This is very important as organoleptic scores are often regarded as subjective, especially by patients with doubts.

However, when using the thresholds proposed by the manufacturers and considering an organoleptic score different from zero as a diagnosis of halitosis, a significant number of patients with oral malodour are incorrectly classified (sensitivity around 60–70%), as they would have no bad breath according to the VSC levels given by the manufacturer of the devices. Moreover if threshold levels are not attained, this does not necessarily mean that there is also no breath malodour organoleptically (NPV around 40–50%). This indicates that the organoleptic assessment should still be considered as the gold standard for diagnosis of oral malodour. For most of the incorrectly classified patients, the organoleptic score was only 1, which represents a very slight malodour that possibly can elicit VSC levels below the boundaries from the manufacturer. However, when using threshold values half of the proposed ones, the sensitivity increased strongly without dramatically decreasing the specificity and half of these patients are then correctly classified. These results indicate that the boundaries proposed by the manufacturers of the two devices are too high and should be reconsidered. Previously, a level of 75 ppb was suggested to be the limit for social acceptance, which is comparable with half of the threshold level proposed by the Halimeter® manufacturer (Yaegaki & Sanada 1992a).

As mentioned above, patients with organoleptic score of 1 could be considered as not having halitosis according to some authors. This way of looking at the organoleptic assessment is reflected in different way for the two devices. While for the Halimeter® the sensitivity was improved (76.3%) without detriment of the specificity (94.2%), this was not the case for the OralChroma™ where the specificity showed an important decrease and the sensitivity had a negligible increase to 75%. Interesting, when the new thresholds were used, there was again an improvement in the sensitivity of both devices (90% for the Halimeter® and 84.4% for the OralChroma™). However, the specificity of both of them was low (67.5% and 70% for the Halimeter® and the OralChroma™, respectively).

There were also a number of patients with a higher organoleptic score that were classified incorrectly. A possible explanation for the wrong classification of these patients could be that under certain circumstances, as for example when saliva dries out on the mucosal surfaces, other components besides sulphur compounds become volatile (Kleinberg et al. 2002).

The values of the sulphur monitors and the organoleptic scores were significantly correlated with the tongue coating score, the periodontal probing depth and the level of oral hygiene. The highest correlations were found for the tongue coating, which is now considered to be the primary source of oral malodour (Coil & Tonzetich 1992, Yaegaki & Sanada 1992b, Bosy et al. 1994, De Boever & Loesche 1995, Miyazaki et al. 1995, Rosenberg 1996). The papillae of the tongue and the crevices of the mucous glands and lingual tonsils increase the accumulation of bacteria and the entrapment of food debris, which favours the growth of anaerobic sulphur-producing bacteria. The correlation between bad breath levels and the periodontal probing depth was weaker. In literature, there is some disagreement as to what extent oral malodour and periodontal disease are related. Several studies have shown a relationship between periodontitis and halitosis. However, not all patients with gingivitis/periodontitis have bad breath and vice versa (Bosy et al. 1994, Stamou et al. 2005, Rosenberg 2006).

The forward variable selection also showed that the tongue coating was the most determining factor for predicting oral score. Parameters such as pocket probing depth, Halimeter® values, OralChroma™ levels of H_2S, and level of oral hygiene were clearly inferior. The latter is in agreement with the above-mentioned studies.

We concluded that within the limitations of this study, measurement of the VSC levels with the Halimeter® or the OralChroma™ can be used as an adjunct to the organoleptic assessment, which is an efficient strategy to detect oral malodour, especially when the threshold levels of these devices are adapted. However, the organoleptic score should still be considered as the ''gold standard'' for diagnosis of bad breath.

Considering the high specificity of the sulphur monitors, these devices can be used to prove the absence of malodour in case of pseudo-halitosis and halitophobia.

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Clinical Relevance

Scientific rationale: Measurement of the VSC levels by portable sulphur monitors (Halimeter®, OralChroma™) is a fast and easy method for diagnosis of oral malodour. This study aimed to investigate the clinical value of these devices.

Principal findings: Both devices showed an excellent specificity (± 100%) but lower sensitivity (± 65%) to detect patients with/without bad breath. Sensitivity could be improved by lowering the proposed threshold values, without a significant decrease in specificity.

Practical implications: Measurement of the VSC levels, together with the organoleptic assessment, is an efficient strategy to detect oral malodour. However, the proposed threshold values should be reconsidered.