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ORIGINAL ARTICLE

Clinical assessment of oral malodor intensity expressed as absolute value using an electronic nose

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OBJECTIVES: In our previous study, scores determined via a multiple linear regression method (EN-MLR) involving an electronic nose provided objective halitosis-related measurements; however, this model afforded only relative expression exclusively. The objective of this investigation was to assess clinically oral malodor intensity expressed as an absolute value using an electronic nose.

SUBJECTS AND METHODS: Sixty-six subjects were evaluated based on results of an actual organoleptic test (OLT), measurements of volatile sulfur compound (VSC) concentrations, a score representing malodor intensity (EN-MI) as the absolute value and EN-MLR measured with an electronic nose system. Oral health parameters were also examined.

RESULTS: The OLT score served as a benchmark. The area under the receiver-operating characteristic (ROC) plots of EN-MI score (0.975) was significantly larger than that of log VSC (0.896) ($P = 0.036$); however, the area did not differ significantly from that of EN-MLR score (0.932). Percentage of teeth with pocket depth ≥4 mm, tongue coating score and plaque control record displayed meaningful association with EN-MI score in multiple logistic regression analyses.

CONCLUSION: Oral malodor intensity expressed as an absolute value employing an electronic nose may be a suitable method for clinical evaluation of oral malodor.
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Keywords: oral malodor; clinical assessment; electronic nose; oral health parameters

Introduction

The two primary methods applicable to clinical analysis of oral malodor are organoleptic test (OLT) and instrumental analysis, such as gas chromatography or use of a portable sulfide monitor (Rosenberg *et al*, 1991). However, since both techniques exhibit disadvantages, there remains no ideal objective approach for clinical assessment of the degree of oral malodor (Rosenberg, 1996). We previously reported that the scores determined with an electronic nose under top-note mode, provided objective halitosis-related measurements. However, those data were obtained via the multiple linear regression method (EN-MLR) and yielded relative rather than absolute values (Tanaka *et al*, 2004a). This investigation attempted to assess clinically oral malodor intensity expressed as an absolute value utilizing an electronic nose.

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Subjects and methods

The subject population consisted of 46 individuals (mean age, 40.8 years) characterized by odor-judge ratings of ≥2.0 and 20 participants (mean age, 41.6 years) with odor-judge ratings of <2.0. Breath malodor was assessed with an electronic nose. Furthermore, volatile sulfur compound (VSC) measurements were conducted on a gas chromatograph; additionally, an OLT was performed.

The FF-1 odor discrimination analyzer (electronic nose, Shimadzu Ltd, Kyoto, Japan) utilized in the present study consisted of a preconcentrator, an array of six metal oxide semiconductor sensors selected for their distinct sensitivity and selectivity to fragrant substances, and pattern recognition software. The electronic nose was calibrated with nine standard gases including hydrogen sulfide, methylmercaptan, ammonia, trimethylamine, propionic acid, butylaldehyde, butylacetate, toluene and heptane (Shimadzu Ltd) before the measurement. The gas sample was introduced into the trap tube for 30 s, and then the trapped odor was driven to the sensor section with pure nitrogen. The odor spectrum was determined for nine categories of gases in the odor space formed by multiple output signals of sensors. The malodor intensity of sample gases as an absolute value was expressed as the vectorial sum of the malodor intensity of each category of gas (Kita *et al*, 2000). The score as a relative value was also obtained via a multiple linear regression method (Tanaka *et al*, 2004a). Probing depth was measured at two points

around each tooth in all subjects and periodontal status was determined as a percentage of teeth displaying probing depth of ≥4 mm. O'Leary's plaque control records were also employed to assess oral hygiene status. In addition, tongue coating scores were determined by multiplying thickness by area (Tanaka *et al*, 2003).

Statistical comparisons of EN-MI, EN-MLR score and VSC level were analyzed using receiver-operating characteristic (ROC) plots with Rockit 0.9B Beta Version. Multiple linear regression and logistic regression analyses served to identify those oral health variables demonstrating a significant independent effect on EN-MI scores.

Results

Correlations between actual OLT score and EN-MI, EN-MLR scores or log total VSC derived from gas chromatography were examined. These three correlation coefficients were 0.81, 0.78 and 0.73, respectively. No meaningful difference was observed among the three correlation coefficients. ROC sensitivity-specificity plots afforded an appropriate protocol for comparison of EN-MI, EN-MLR scores and log total VSC data for classification of subjects with or without actual OLT score ≥2.0. Area under the ROC plots representing EN-MI scores (0.975) was markedly larger than that of log VSC (0.896) ($P = 0.036$); however, it did not differ significantly from that of EN-MLR (0.932) (Figure 1).

Logistic regression analyses were conducted which corresponded to the possibility of placement of subjects in the upper 25th percentile of EN-MI score distribution as a dependent variable. Percentage of teeth exhibiting probing depth of ≥4 mm, tongue coating score and plaque control record displayed significant association with EN-MI scores (odds ratios of 13.0, 7.1 and 28.2, respectively) ($P < 0.05$).

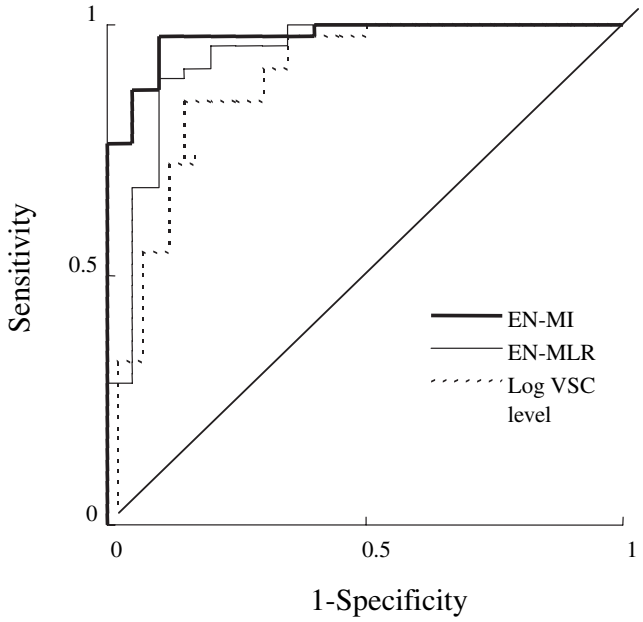

Figure 1 ROC plots comparing EN-MI, EN-MLR and log VSC data utilized for classification of subjects with or without OLT score of ≥2.0. Areas under ROC plots were 0.975 (EN-MI), 0.932 (EN-MLR) and 0.896 (log VSC)

Discussion

In the present investigation, EN-MI scores were compared with EN-MLR scores as oral malodor assessment employing an electronic nose system. The correlation coefficient between EN-MI score and OLT score ($r = 0.81$) was nearly identical to that between EN-MLR and OLT score ($r = 0.78$). Area under the ROC curve representing EM-MI score was also similar to that of EN-MLR; in contrast, it was significantly larger than that of log VSC. This finding suggests that EN-MI score determined with the electronic nose demonstrated a level of accuracy higher than that of log VSC for classification of subjects with or without actual OLT score of ≥2.0.

This study also established that EN-MI scores were independently correlated with periodontal health status, tongue coating and supra-gingival plaque accumulation. These results were consistent with those of EN-MLR scores (Tanaka *et al*, 2004a). We also previously reported that the periodontal pathogens on tongue dorsa contributed markedly to VSC production (Tanaka *et al*, 2004b). However, since the proportions of periodontal pathogens were weakly associated with OLT score, we suggested that other malodorous compounds in addition to VSC might also be related to OLT scores (Tanaka *et al*, 2004b). EN-MI may be attributed to various malodorous compounds which may be produced mainly at supra-gingival plaque, periodontal pocket and tongue coating. Thus, the relationship between amount of supra-gingival plaque, periodontal pocket depth and tongue coating and oral malodor may be effectively detected by EN-MI. We conclude that the absolute expression of malodor intensity with an electronic nose can afford objective halitosis-related measurements.

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