Efficacy of a Chlorine Dioxide–Containing Mouthrinse in Oral Malodor

Abstract: Studies have suggested that when chlorine dioxide is contained in a mouthrinse, it neutralizes volatile sulfur compounds in mouth air. The efficacy of a chlorine dioxide–containing mouthrinse in the reduction of oral malodor was evaluated in a randomized, controlled, double-blind, parallel group study of 31 men and women. Subjects with a maximum odor pleasantness score of ≤ −1 (slightly unpleasant/stale) on a 7-point ordinal scale at both screening and baseline were randomized to treatment with the chlorine dioxide–containing rinse (n = 16) or distilled water (negative control) (n = 15). Oral malodor was evaluated at baseline (prerinse) and at 2, 4, 8, 24, 48, 72, and 96 hours postrinse by both a trained, previously calibrated panel of organoleptic judges and a factory-calibrated portable sulfide monitor. The sulfide monitor measured concentrations of volatile sulfur compounds in the subjects' mouth air 3 minutes after completion of the organoleptic assessment at each time point. The correlation between the organoleptic assessments and log-transformed sulfide monitor values was evaluated. With the chlorine dioxide mouthrinse, a statistically significant improvement in odor pleasantness, reduction in odor intensity, and reduction in oral volatile sulfur compound concentrations compared to the water control were evident at 2 hours postrinse and persisted through 8 hours postrinse. The mean (± SD) odor pleasantness improved from −1.25 ± 0.31 at baseline to −0.73 ± 0.33 at 2 hours postrinse in the chlorine dioxide group compared to −1.40 ± 0.38 at baseline to −1.31 ± 0.67 at 2 hours in the control group (P < .01). Odor pleasantness reached its maximum change from baseline to 0.63 ± 0.45 at 8 hours postrinse. The mean (± SD) log-transformed sulfide monitor measurement decreased from 5.40 ± 0.29 at baseline to 5.17 ± 0.13 at 2 hours postrinse in the chlorine dioxide group, but increased from 5.47 ± 0.40 at baseline to 5.66 ± 0.54 at 2 hours in the control group (P < .01). As measured by the sulfide monitor, the mean volatile sulfur compound concentration in the chlorine dioxide group reached its minimum level at 8 hours postrinse (change from baseline in the log-transformed Halimeter® measurement of −0.35 ± 0.31). Thus, this study demonstrates that a one-time use of a chlorine dioxide–containing mouthrinse significantly improves mouth odor pleasantness, reduces mouth odor intensity, and reduces volatile sulfur compound concentrations in mouth air for at least 8 hours after use.

The growing interest in halitosis (bad breath) is evidenced by the proliferation of diagnostic and treatment services offered in many dental offices and breath clinics. Bad breath is most often caused by oral conditions, including poor general oral hygiene, periodontal diseases, dry mouth (transient or chronic), food impaction, improper or faulty restorations, unclean dentures, excessive bacterial growth on the dorsum of the tongue, throat infections, and oral carcinomas; nonoral etiologies are rare.

The principal source of oral malodor is bacterial stagnation in grooves, fissures, and interpapillary areas of the dorsoposterior surface of the tongue. Mass spectrometric and gas chromatographic studies have shown that volatile sulfur compounds (VSCs), including hydrogen sulfide (H₂S), methyl mercaptan

Learning Objectives:

- discuss the efficacy of a chlorine dioxide–containing mouthrinse in reducing oral malodor.
- evaluate the use of serial organoleptic and Halimeter® measurements for characterizing oral malodor.
- discuss the correlation between volatile sulfur compounds and oral malodor.
- compare the affect of commercially available mouthrinses vs a chlorine dioxide–containing mouthrinse.
(CH$_3$SH), and, to a lesser extent, dimethyl sulfide (CH$_3$SCH$_3$), are the principal malodorants in bad breath. Hydrogen sulfide is produced primarily from the tongue dorsum, while methyl mercaptan and dimethyl disulfide enrich the malodor produced by periodontal tissues. In the mouth, VSCs originate from the anaerobic bacterial activity on sulfur-containing amino acids derived from degraded proteins present in salivary filtrate. Although commonly associated with such conditions as chronic halitosis and periodontal disease, VSCs are detectable in the mouth air of normal (i.e., dentally healthy) individuals. Following the application of cysteine as a mouthrinse, VSCs have been produced in the mouths of healthy subjects with no history of halitosis.

Clinical use of a mouthrinse containing chlorine dioxide can be expected to reduce oral malodor by reducing concentrations of VSCs.

Reliable and reproducible assessment of oral malodor has been difficult to achieve. Organoleptic or hedonic assessment, the simplest and most commonly used method of measuring oral malodor, involves the direct nasal sniffing of mouth air. Organoleptic assessment by a panel of sensory judges is considered a reference standard of oral malodor measurement because it closely approximates the way in which bad breath is detected. However, researchers have observed variation between judges on scoring the degree of unpleasantness of various odors. The reliability and reproducibility of measurement may be improved if the judges are trained to recognize and rate oral malodor. Although agreement among judges may be increased if they are previously instructed to assign specific scores to designated odor stimuli, reproducible olfactory standards do not exist. Attempts to create such standards have included the use of mass spectrographic and gas chromatographic techniques and, more recently, portable sulfide monitors adapted for use in oral malodor research.

Studies have suggested that when chlorine dioxide is contained in a mouthrinse, it neutralizes VSCs in mouth air. In experimental models, use of a mouthrinse containing a mixture of chlorine dioxide and chlorite anion has been shown to result in oxidative consumption of the amino acids cysteine and methionine, which are precursors of VSCs. Thus, clinical use of a mouthrinse containing chlorine dioxide can be expected to reduce oral malodor by reducing concentrations of VSCs. In contrast, commercially available mouthwashes have no significant effect on oral malodor.

The objective of the present study was to investigate the efficacy of a chlorine dioxide mouthrinse in reducing oral malodor over a 96-hour period following a single 30-second rinse. The study used a double-blind, randomized, parallel group design, with distilled water serving as a negative control. Organoleptic assessment was used to characterize the pleasantness and intensity of the subjects' oral malodor, and a portable sulfide monitor was used to provide a quantitative measure of oral VSC concentrations for each time point that organoleptic evaluations were recorded.

Materials and Methods

Study Treatments

The chlorine dioxide-containing mouthrinse used as the test treatment in this study was CloSYSII® (formerly RetarDEX® oral rinse), which is 0.1% stabilized chlorine dioxide in aqueous solution. The treatment was administered in blinded containers without the addition of an optional mint flavoring agent. Distilled water, used as a negative control in this study, was indistinguishable by taste, odor, or appearance from the test treatment.

Subjects and Selection Criteria

Thirty-one subjects were enrolled in the study and randomized for treatment with either the test mouthrinse (n = 16) or distilled water (n = 15). Twenty-four (77.4%) of the subjects were women and 7 (22.6%) were men. The subjects ranged in age from 27 to 70 years. There were no statistically significant differences between the treatment groups with respect to gender, ethnicity, or age. The study protocol was approved by an Institutional Review Board and written informed consent was obtained from all subjects before the start of screening procedures. All subjects enrolled completed the study according to protocol.

Subjects were eligible for inclusion in the
trial if they were in good general health; at least 18 years of age; capable of understanding the plan and scope of the study with respect to subject participation and giving informed consent; and had an average odor pleasantness score of ≤−1.0 (slightly unpleasant/stale) assigned by the organoleptic panel at screening and at baseline. Subjects were excluded if they had a known allergy to any ingredients found in dental products; preexisting oral irritations; had gingival surgery within the 6 months before screening; had full dentures, partial dentures, or orthodontic appliances; were pregnant or lactating; had halitosis because of known factors other than oropharyngeal bacteria (eg, diabetes); or used any daily medication that might interfere with the performance of the study according to protocol. A thorough intraoral examination was performed at screening to determine whether subjects met the inclusion or exclusion criteria.

**General Study Procedures**

The subjects were instructed to abstain from oral hygiene (ie, to refrain from brushing, flossing, or rinsing their mouths) beginning at midnight before each study visit. They were permitted to eat and drink on the morning of the study visit, but were instructed to avoid eating foods that could impart a strong residual odor. Smoking on the morning of the assessments was not permitted. The subjects also refrained from using hair spray, cologne, perfume, or strong detergents so as not to distract the judges.

The subjects remained at the study site for the first 4 hours after rinsing. They were permitted to drink only water during this period. The subjects returned to the study site for the 8-, 24-, 48-, 72-, and 96-hour assessments, having observed the restrictions on food, drink, and oral hygiene required by protocol. The subjects' study participation culminated with completion of the 96-hour sulfide monitor measurements.

**Efficacy Assessments**

**Organoleptic Assessments**

An experienced panel of three sensory judges performed all organoleptic assessments. All of the judges had been selected, trained, and previously calibrated according to standardized criteria. All subjects were evaluated by each of the three judges at 0 hour (baseline/prerinse) and at 2, 4, 8, 24, 48, 72, and 96 hours postrinse. Odor pleasantness was rated on a 7-point bidirectional scale as follows: very pleasant/fresh (+3), moderately pleasant/fresh (+2), slightly pleasant/fresh (+1), neutral or no significant breath odor (0), slightly unpleasant/stale (−1), moderately unpleasant/stale (−2), or very unpleasant/stale (−3). Odor intensity was rated on a 4-point categorical scale as follows: none (0), slight (1), moderate (2), strong (3), or very strong (4).

For each scheduled assessment of odor pleasantness and intensity, each subject was given a bonded paper-covered tube and instructed to insert the tube through the opening of a curtain behind which a judge was stationed. The judge was instructed to notify the
Table 2—Mean Odor Intensity Scores: Summary of Between-Group Comparisons and Within-Group Changes from Baseline

<table>
<thead>
<tr>
<th>Time</th>
<th>Treatment</th>
<th>Chlorine Dioxide Rinse</th>
<th>Distilled Water</th>
<th>P-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1.27 (0.30)</td>
<td>1.42 (0.46)</td>
<td>0.29</td>
</tr>
<tr>
<td>2</td>
<td>Mean (SD)</td>
<td>0.81 (0.38)</td>
<td>1.40 (0.70)</td>
<td>&lt;0.01</td>
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<tr>
<td></td>
<td>Change from O</td>
<td>-0.46 (0.32)</td>
<td>-0.02 (0.70)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P-value (Change)</td>
<td>&lt;0.01</td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Mean (SD)</td>
<td>0.94 (0.46)</td>
<td>1.56 (0.86)</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Change from O</td>
<td>-0.33 (0.50)</td>
<td>0.13 (0.77)</td>
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<tr>
<td></td>
<td>P-value (Change)</td>
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<td>0.52</td>
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<td>8</td>
<td>Mean (SD)</td>
<td>0.63 (0.42)</td>
<td>1.29 (0.73)</td>
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<tr>
<td></td>
<td>Change from O</td>
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<td>-0.13 (0.66)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P-value (Change)</td>
<td>&lt;0.01</td>
<td>0.45</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Mean (SD)</td>
<td>0.96 (0.47)</td>
<td>1.22 (0.71)</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>Change from O</td>
<td>-0.31 (0.45)</td>
<td>-0.20 (0.79)</td>
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</tr>
<tr>
<td></td>
<td>P-value (Change)</td>
<td>0.01</td>
<td>0.35</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>Mean (SD)</td>
<td>1.21 (0.57)</td>
<td>1.31 (0.76)</td>
<td>0.67</td>
</tr>
<tr>
<td></td>
<td>Change from O</td>
<td>-0.06 (0.57)</td>
<td>-0.11 (0.67)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P-value (Change)</td>
<td>0.67</td>
<td>0.53</td>
<td></td>
</tr>
<tr>
<td>72</td>
<td>Mean (SD)</td>
<td>1.21 (0.58)</td>
<td>1.29 (0.86)</td>
<td>0.76</td>
</tr>
<tr>
<td></td>
<td>Change from O</td>
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<td>-0.13 (0.89)</td>
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<td>P-value (Change)</td>
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<td>0.57</td>
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<tr>
<td>96</td>
<td>Mean (SD)</td>
<td>1.21 (0.48)</td>
<td>1.40 (0.66)</td>
<td>0.36</td>
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<td></td>
<td>Change from O</td>
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<tr>
<td></td>
<td>P-value (Change)</td>
<td>0.53</td>
<td>0.89</td>
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</table>

*P-value for between-group comparisons is based on 2-sample t test

obtain all measurements of VSC in the subjects' mouth air. The only function of the Halimeter® is to serve as a reliable monitor for the measurement of VSC concentrations, which it quantifies at the parts-per-billion (ppb) level.

After completing the organoleptic assessment, the subjects, with their mouths closed, proceeded in single file to a second odor grading station for VSC evaluation. Once there, each subject connected one end of a clean straw to the Halimeter® and kept the mouth closed for approximately 30 seconds. While holding the breath, the subject then placed the mouth over the free end of the straw. The Halimeter® then drew air from the subject’s mouth. The measured VSC value indicated by the instrument was recorded on the case report form by the clinical staff. As stipulated in the Halimeter® specifications, three replicate measurement readings were obtained from each subject at each time point and averaged for a single score. The Halimeter® was reset to zero for ambient room air before each recording.

Statistical Methods

Organoleptic Assessments—Descriptive statistics (means and standard deviations) were used to summarize the average of the assessments of the three judges at all time points. Between-group differences in organoleptic assessments were tested using the t test at the 5% level of significance. Within-group changes from prerinse levels to each postrinse time point were analyzed using the paired t test at the 5% level of significance.

The apparent lack of homogeneity between the two treatment groups with respect to odor pleasantness at baseline, while not statistically significant, prompted a supplementary statistical analysis of the effect of baseline scores on posttreatment odor pleasantness. Odor pleasantness scores were analyzed at each postrinse time point using an analysis of covariance with the baseline score as the covariate.

VSC Measurements—The three replicate measurements obtained from each subject at
Table 3—Log-Transformed VSC Measurements: Summary of Between-Group Comparisons and Within-Group Changes from Baseline

<table>
<thead>
<tr>
<th>Time</th>
<th>Treatment</th>
<th>P-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chlorine Dioxide Rinse</td>
<td>Distilled Water</td>
</tr>
<tr>
<td>0</td>
<td>Mean (SD)</td>
<td>5.40 (0.29)</td>
</tr>
<tr>
<td></td>
<td>Change from 0</td>
<td>-0.24 (0.21)</td>
</tr>
<tr>
<td></td>
<td>P-value (Change)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>4</td>
<td>Mean (SD)</td>
<td>5.19 (0.15)</td>
</tr>
<tr>
<td></td>
<td>Change from 0</td>
<td>-0.22 (0.28)</td>
</tr>
<tr>
<td></td>
<td>P-value (Change)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>8</td>
<td>Mean (SD)</td>
<td>5.05 (0.11)</td>
</tr>
<tr>
<td></td>
<td>Change from 0</td>
<td>-0.35 (0.31)</td>
</tr>
<tr>
<td></td>
<td>P-value (Change)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>24</td>
<td>Mean (SD)</td>
<td>5.22 (0.12)</td>
</tr>
<tr>
<td></td>
<td>Change from 0</td>
<td>-0.18 (0.31)</td>
</tr>
<tr>
<td></td>
<td>P-value (Change)</td>
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<tr>
<td>48</td>
<td>Mean (SD)</td>
<td>5.27 (0.25)</td>
</tr>
<tr>
<td></td>
<td>Change from 0</td>
<td>-0.13 (0.32)</td>
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<tr>
<td></td>
<td>P-value (Change)</td>
<td>0.12</td>
</tr>
<tr>
<td>72</td>
<td>Mean (SD)</td>
<td>5.23 (0.34)</td>
</tr>
<tr>
<td></td>
<td>Change from 0</td>
<td>-0.18 (0.36)</td>
</tr>
<tr>
<td></td>
<td>P-value (Change)</td>
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<tr>
<td>96</td>
<td>Mean (SD)</td>
<td>5.25 (0.27)</td>
</tr>
<tr>
<td></td>
<td>Change from 0</td>
<td>-0.16 (0.23)</td>
</tr>
<tr>
<td></td>
<td>P-value (Change)</td>
<td>0.01</td>
</tr>
</tbody>
</table>

* P-value for between-group comparisons is based on 2-sample t test.

Results

Odor Pleasantness

Table 1 summarizes odor pleasantness scores for the average of the three-judge panel at all time points. There was no statistically significant difference between the chlorine dioxide and control groups at baseline (0 hour). The mean (± SD) odor pleasantness improved from -1.25 ± 0.31 at baseline to -0.73 ± 0.33 at 2 hours postrinse in the chlorine dioxide group compared to -1.40 ± 0.38 at baseline to -1.31 ± 0.67 at 2 hours in the control group. Two-sample t tests showed that the between-group difference in odor pleasantness scores was statistically significant at 2 hours (P <0.01), 4 hours (P = 0.01), and 8 hours (P <0.01) postrinse (Table 1). The mean (± SD) odor pleasantness in the chlorine dioxide group reached its maximum level of -0.63 ± 0.42, indicating the greatest increase in odor pleasantness, at 8 hours postrinse.

Analyses of within-group changes from baseline in the chlorine dioxide group using a 1-sample t test showed statistically significant increases from baseline in odor pleasantness at 2, 4, 8, and 24 hours postrinse (P <0.01, P = 0.02, P <0.01, and P <0.01, respectively), whereas the control group showed no significant increases from baseline postrinse at any time point during the study (Table 1).

The apparent lack of homogeneity between the two treatment groups with respect to odor pleasantness at baseline, while not statistically significant, prompted a supplementary statistical analysis of the effect of baseline scores on posttreatment odor pleasantness. This analysis (ANCOVA) confirmed the presence of a statistically significant treatment effect (test > control) at 2, 4, and 8 hours postrinse, even after adjustment for the effect of baseline differences in the statistical model.

Odor Intensity

Odor intensity scores for the average of the three-judge panel at all time points are summa-
rized in Table 2. There was no statistically significant difference between the chlorine dioxide and control groups at baseline (0 hour). The mean (± SD) odor intensity decreased from 1.27 ± 0.30 at baseline to 0.81 ± 0.38 at 2 hours postrinse in the chlorine dioxide group compared to 1.42 ± 0.46 at baseline to 1.40 ± 0.70 at 2 hours in the control group. Two-sample t tests showed that the between-group difference in odor intensity scores was statistically significant at 2 hours (P < 0.01), 4 hours (P = 0.02), and 8 hours (P < 0.01) postrinse (Table 2). The mean (± SD) odor intensity in the chlorine dioxide group reached its minimum level of 0.63 ± 0.42, indicating the greatest decrease in odor intensity, at 8 hours postrinse.

Analysis of within-group changes from baseline in the chlorine dioxide group using a 1-sample t test showed statistically significant reductions from baseline in odor intensity at 2, 4, 8, and 24 hours postrinse (P < 0.01, P = 0.02, P < 0.01, and P = 0.01, respectively), whereas the control group showed no significant reductions from baseline at any time point postrinse (Table 2).

**VSC Measurements**

The mean log-transformed VSC measurements using the Halimeter® at all time points are summarized in Table 3. There was no statistically significant difference between the chlorine dioxide and control groups at baseline (0 hour). The mean (± SD) log-transformed VSC measurement decreased from 5.40 ± 0.29 at baseline to 5.17 ± 0.13 at 2 hours postrinse in the chlorine dioxide group, but increased from 5.47 ± 0.40 at baseline to 5.56 ± 0.54 at 2 hours in the control group. Two-sample t tests showed that the between-group difference in VSC measurements was statistically significant at 2 hours (P < 0.01), 4 hours (P < 0.01), and 8 hours (P = 0.05) postrinse and approached significance at 24 hours (P = 0.07) postrinse (Table 3). As measured by the Halimeter®, the mean VSC concentration in the chlorine dioxide group reached its minimum level, corresponding to a log-transformed Halimeter® reading of 5.05 ± 0.11, at 8 hours postrinse.

Analysis of within-group changes from baseline using the paired t test showed that the chlorine dioxide group had statistically significant reductions in VSC concentrations at 2, 4, 8, 24, and 96 hours postrinse (P < 0.01, P < 0.01, P < 0.01, and P = 0.04, respectively), and a reduction approaching significance at 72 hours postrinse (P = 0.07). The control group had significant reductions in VSC concentrations from baseline at 8, 48, 72, and 96 hours (P < 0.01, P = 0.01, P = 0.05, and P < 0.01, respectively), and reductions approaching significance at 4 hours postrinse (P = 0.06) (Table 3).

**Correlation of Odor Pleasantness Scores With Levels of VSC**

The changes in odor pleasantness scores and levels of VSC as measured by the Halimeter® at all time points postrinse are depicted graphically in Figure 1. Statistically significant differences (P < 0.05) between treatments in odor pleasantness and VSC levels were detected at 2, 4, and 8 hours postrinse. The partial correlation coefficient calculated between the odor pleasantness scores and concentrations of VSC in mouth air as measured by the Halimeter® was 0.277 with 203 df for error and a significance level less than 0.001. Thus, the improvement in organoleptically assessed breath odor pleasantness was positively correlated with the reduction in concentrations of VSC in mouth air.

**Discussion**

The organoleptic assessments of breath odor pleasantness and intensity showed statistically significant malodor reduction with
chlorine dioxide compared to distilled water at 2, 4, and 8 hours posttine. These findings were paralleled by statistically significant reductions in VSC concentrations as measured by the Halimeter® at the same time points. The statistically significant correlation between odor pleasantness scores and Halimeter® measurements is consistent with previous findings that VSC are the principal malodorants in bad breath.5,5

Individuals with low concentrations of methyl mercaptan relative to hydrogen sulfide may have elevated Halimeter® measurements and no organoleptically discernible breath malodor.

A potential limitation of this study is that the subjects' malodor was assessed sequentially, rather than simultaneously, by the members of the organoleptic panel at any given time point posttine. This limitation is shared by most studies that use both organoleptic and instrumental assessments of oral malodor, and that require organoleptic assessment by more than one judge. It has been pointed out that once the oral head space is sampled for measurement by one judge, it is unlikely that the concentration and composition of the various gases are reproduced in subsequent samples.9 Moreover, sensory comparisons should be made at approximately equivalent concentrations of the chemical entity or entities under the study.13 The first observation, however, relates to organoleptic assessments of expelled mouth air. In the present study, every effort was made to minimize sources of odor variability by having the subjects expel no air during either the organoleptic assessments or the VSC evaluations and keep their mouths closed between organoleptic assessments and VSC evaluations.

An additional limitation of the study is that both the objective and subjective methods used to characterize oral malodor showed a slight downward drift over time in both the active- and placebo-treated subjects. A slight downward drift in Halimeter® measurements over time has been reported by other researchers and may reflect a possible loss of machine sensitivity as a result of contamination of the hydrogen sulfide sensor with sulfide-containing components.12 For this reason, the utility of the Halimeter® would be improved if accurate laboratory standards were readily available for daily calibration of the machine.12 The parallel downward drift noted in the organoleptic assessments may indicate affective habituation of the organoleptic judges to the unpleasant substances contributing to the subjects' oral malodor.19,20 Despite the observed downward drift, both the Halimeter® and the organoleptic panel were able to differentiate the effects of the active mouthrinse from those of the water control through 8 hours posttine.

The low-to-moderate correlation observed between the organoleptic assessments of oral malodor and the Halimeter® measurements of VSC concentration in the subjects' mouth air may have resulted from a combination of two important factors. First, the entry criteria stipulated that the subjects demonstrate good general health, and it has been shown that the principal malodorant in the mouth air of normal individuals is hydrogen sulfide.21,3 Second, although the Halimeter® quantifies concentrations of VSC at the ppb level, it is approximately twice as sensitive to hydrogen sulfide as it is to methyl mercaptan.5,13 Thus, individuals with low concentrations of methyl mercaptan relative to hydrogen sulfide may have elevated Halimeter® measurements and no organoleptically discernible breath malodor.5 The significant correlation between organoleptic assessments and Halimeter® measurements in the present study suggests that hydrogen sulfide was the principal component of the subjects' malodor. However, a definitive statement concerning the correlation between the concentrations of hydrogen sulfide in the subjects' mouth air and the organoleptic panel's assessments is beyond the scope of the present study.

In conclusion, this study successfully used serial organoleptic and Halimeter® measurements to characterize the duration of action of a chlorine dioxide-containing mouthrinse on oral malodor during the period beginning at baseline and continuing through 96 hours posttine. The organoleptic panel's subjective assessments were validated by concurrent use of an objective measure of volatile substances, which contributed to the subjects' oral malodor. The data show that a single 15-mL application of a chlorine dioxide-containing mouthrinse improves breath odor pleasantness, reduces breath odor malodor, and reduces
VSC concentrations in mouth air through 8 hours after use.

Disclosure
This study was supported by a grant from Rowpar Pharmaceuticals, Inc.

References
1. Bad breath is most often caused by oral conditions including:
   a. dry mouth.
   b. food impaction.
   c. improper or faulty restorations.
   d. all of the above

2. The VSCs recognized as being the principal malodorants in bad breath are:
   a. methyl mercaptan and dimethyl sulfide.
   b. hydrogen sulfide and methyl mercaptan.
   c. hydrogen sulfide, methyl mercaptan and dimethyl sulfide.
   d. hydrogen sulfide and dimethyl sulfide.

3. The VSC primarily produced from the tongue dorsum is:
   a. dimethyl sulfide.
   b. methyl mercaptan and dimethyl sulfide.
   c. hydrogen sulfide.
   d. methyl mercaptan and hydrogen sulfide.

4. Which of the following are precursors of VSCs?
   a. arginine and leucine
   b. ethylamine and methylamine
   c. phenylamine and propylamine
   d. cysteine and methionine

5. The Halimeter® was used to:
   a. determine the pH of saliva.
   b. collect subgingival fluid samples.
   c. measure VSC concentrations.
   d. sonicate anaerobic bacteria resulting in decreased odor.

6. The organoleptic assessments of breath odor pleasantness and intensity showed statistically significant malodor reduction with chlorine dioxide compared to distilled water:
   a. up to 1 hour postrinse.
   b. up to 3 hours postrinse.
   c. through 8 hours postrinse.
   d. through 96 hours postrinse.

7. A potential limitation of this study is that the subjects' malodor was assessed:
   a. sequentially, rather than simultaneously.
   b. simultaneously, rather than sequentially.
   c. immediately.
   d. after 96 hours.

8. In the present study, every effort was made to minimize sources of odor variability by:
   a. having the subjects expel no air during the organoleptic assessment.
   b. having the subjects expel no air during the VSC evaluations.
   c. having the subjects keep their mouths closed between assessments.
   d. all of the above

9. A downward drift of the Halimeter® measurements over time may be attributed to:
   a. contamination of the hydrogen sulfide sensor.
   b. habituation of the Halimeter® to breath.
   c. decreased intraoral VSCs.
   d. all of the above

10. The significant correlation between the organoleptic assessments and the Halimeter® measurements suggests that:
    a. dimethyl sulfide was the principal component of the subjects' malodor.
    b. hydrogen sulfide was the principal component in the subjects' malodor.
    c. there were no VSCs in the subjects' malodor.
    d. the subjects demonstrated no malodor.