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Clinical trial of oral malodor treatment in patients with periodontal diseases

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Background and Objective: Only a few clinical research studies have assessed different therapeutic approaches to oral malodor in subjects affected by periodontal diseases. The aim of this study was to evaluate the effects of periodontal treatment and tongue cleaning on oral malodor parameters in periodontitis and gingivitis patients.

Material and Methods: The subjects were 102 periodontitis and 116 gingivitis patients with oral malodor. Oral malodor was measured by organoleptic test and Oral Chroma™. Oral health status, including tooth conditions, periodontal health, tongue coating and proteolytic activity of the BANA test in tongue coating were assessed. Subjects in each periodontal disease group were randomly assigned into two subgroups depending on the sequence of treatment: periodontal treatment and tongue cleaning. Oral malodor and oral health parameters were compared by groups and sequence of treatment.

Results: For subjects in the periodontitis group, there were statistically significant reductions in oral malodor after periodontitis treatment or tongue cleaning; however, major reductions were found after periodontitis treatment. For those in the gingivitis group, there were also statistically significant reductions in oral malodor after gingivitis treatment or tongue cleaning, but the most marked reductions were observed after tongue cleaning. At the completion of treatment, all oral malodor parameters fell below the threshold levels in all subgroups.

Conclusion: The present study indicated that periodontal treatment played an important role and tongue cleaning contributed to a lesser extent to reduction in oral malodor in periodontitis patients. In contrast, tongue cleaning alone can be the primary approach to reduce oral malodor in gingivitis patients.

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Halitosis is an unpleasant or offensive odor emanating from the breath, which is also called oral malodor. Though oral malodor has complex etiology with extra- and intraoral origins, it is widely accepted that 85–90% of oral malodor originates from the oral cavity (1–3). The principal components of oral malodor are volatile sulfur compounds, which are primarily hydrogen sulphide (H_2S) and methyl mercaptan (CH_3SH), produced through the putrefaction of proteins containing methionine or cysteine by oral anaerobic gram-negative microorganisms (4–6). Among these bacteria, specific periodontal pathogens, such as *Porphyromonas gingivalis*, *Treponema denticola* and *Tannerella forsythia*, are the most active volatile sulfur compound producers *in vitro* (7,8). There is a correlation between volatile sulfur compounds in mouth air and the extent of periodontal disease. It implies that these organisms, which increase in the subgingival plaque when there is periodontal inflammation, can

contribute to volatile sulfur compound production (9–12).

Tongue coating, which mainly comprises bacteria, large amounts of desquamated epithelial cells released from the oral mucosa, leukocytes from periodontal pockets and blood metabolites, is also an important factor for oral malodor production in both periodontally diseased and healthy people (9,13–15). The structure of the tongue, with its fissures and crypts, provides a large surface area for accumulation of oral debris and microorganisms (16). Hence, periodontal treatment and removal of tongue coating can be expected to improve oral malodor by reducing the number of perio-pathogens in oral malodor patients.

Many epidemiological studies have reported that about one-third of the general population suffers from halitosis (3,17,18). Halitosis can be a factor in negative human relationships and may cause significant social or psychological communication problems in daily life. People suffering from halitosis create a social barrier between themselves and their friends, relatives, partners or colleagues at work (19), and often seek professional dental care for their perceived oral malodor. Therefore, it is important for dental professionals to provide an appropriate protocol for oral malodor treatment, based on an adequate diagnosis and the implementation of a cause-related therapy.

A substantial body of research has been reported on the effects of dentifrices (20,21), mouth rinse (22–24) and chewing gums (25,26) on oral malodor reduction. However, few clinical studies have assessed the efficacy of a treatment regimen combining periodontal treatment with tongue cleaning for the improvement of oral malodor in patients with periodontal diseases.

The hypothesis of the present study was that periodontal treatment or tongue cleaning would be effective to reduce oral malodor, but with different degrees in the periodontitis and gingivitis patients. Therefore, the purpose of the present study was to evaluate the degree of the impact of periodontal treatment and tongue cleaning on oral malodor outcomes in periodontitis and gingivitis patients with oral malodor.

Material and methods

Subjects

The subjects were 229 dentate patients aged 25–60 years, who were diagnosed with oral malodor and recruited at the Periodontal Department of the National Hospital of Odonto-Stomatology in Hochiminh city, Vietnam in 2009. All the subjects had not received any periodontal treatments (prophylactic scaling, root planing and periodontal surgery) or tongue-cleaning instruction within the last 6 mo. Subjects who suffered from any major systemic diseases (diabetes mellitus, gastrointestinal disorders, respiratory dysfunction, neoplasia, various carcinomas, etc.) or who were pregnant or lactating were excluded from the study (27). Prior to the commencement of the study, eligible subjects were provided with information regarding the purpose of the study with an informed consent form. Eleven of the 229 subjects did not complete the treatment procedures; thus, 218 (105 men and 113 women, mean age 42.6 ± 8.5 years) was the final number of subjects in this study. Ethical approval for this study was obtained from the National Hospital of Odonto-Stomatology in Hochiminh city, Vietnam and Tokyo Medical and Dental University, Japan.

Questionnaire

At baseline, all subjects completed self-administered questionnaires concerning demographic information (age and sex) and dental health behaviors (tooth and tongue brushing, experience of oral hygiene instruction and smoking) before the measurement of oral malodor and oral examination.

Measurement of oral malodor

Oral malodor was measured by organoleptic test and Oral Chroma™ (Abilit, Osaka, Japan) prior to the oral examination. Subjects were requested not to do the following (i) consume food such as onions and garlic 48 h before the measurement; (ii) drink alcohol, use mouth rinse and smoke for the previous 12 h; (iii) perform oral hygiene (tooth brushing, interdental and tongue cleaning) for the previous 2 h; (iv) eat and drink for the previous 2 h; and (v) use scented cosmetics on the morning of the examination.

For the organoleptic test, a trained examiner assessed the mouth odor for all subjects. Subjects were asked to close their lips tightly for 3 min while sitting upright in a dental chair and then exhale briefly from the mouth through a paper tube. The results from the organoleptic assessment were rated using a scale ranging from 0 to 5 as follows: 0, no odor; 1, questionable odor; 2, slight but clearly noticeable odor; 3, moderate odor; 4, strong odor; and 5, severe odor (11,28). The subjects were diagnosed as having oral malodor when their organoleptic score was 2 or greater (29).

In the measurement by Oral Chroma™, a disposable 1 mL capacity syringe was inserted into the subject's mouth. A volume of 0.5 mL air was sampled and then injected into the inlet of the device. The volatile sulfur compounds were analyzed automatically and displayed as H_2S and CH_3SH concentrations in nanograms per 10 milliliters. The threshold levels of oral malodor used in this study were those suggested by the previous study: $H_2S > 1.5$ ng/10 mL and $CH_3SH > 0.5$ ng/10 mL (4).

Oral examination

The oral examination included caries experience, plaque index and gingival index (30). Pocket depth and clinical attachment level were evaluated at six sites on each tooth using a Williams 1 mm scaled periodontal probe. The deepest pocket and highest clinical attachment level values were recorded for the tooth. Periodontal status of the tooth with 5 mm or greater pocket was also confirmed radiographically if the greatest bone loss was more than one-third of the root. Gingival bleeding on probing was assessed as presence or absence in 30 s after probing (31). All the teeth excluding the third molars were examined. Subjects were diagnosed

with periodontitis if they had at least one tooth with 5 mm or greater pocket depth or with gingivitis if they had at least one tooth with gingival bleeding on probing and no tooth with 5 mm or greater pocket depth.

The thickness of the tongue coating was evaluated by the same examiner. The tongue dorsum was divided into nine sections. For each of the nine sections, tongue coating was visually assessed and categorized as 0 (no coating), 1 (light coating) or 2 (thick coating). The total score was obtained by adding nine scores, which gave a range of 0–18 (32–34).

BANA test

The presence of putative pathogens, *P. gingivalis*, *T. denticola* and *T. forsythia*, in the tongue coating was detected based on their ability to hydrolyze the synthetic trypsin substrate, named *N*-benzoyl-DL-arginine-2-napthilamide (BANA) (35) by the BANA test (BANAMet LLC, Ann Arbor, MI, USA).

A sample of tongue coating taken from the posterior dorsum of the tongue was immediately placed on the lower portion of the BANA test strip, while the upper portion was moistened with distilled water. The strip was folded over at the crease mark so that they contacted each other, and placed in an incubator for 5 min at 35°C (36). The BANA test scores were recorded as follows: 0 (negative) when no blue color was visible; 1 (weak positive) when a faint blue color was detected; and 2 (positive) when a distinct blue color appeared.

Research design

A flow chart of oral malodor treatment in this study is shown in Fig. 1. As none of 229 participants was periodontally healthy, 111 subjects were grouped into the periodontitis group and 118 subjects into the gingivitis group. Subjects in the periodontitis group were further randomly assigned into two subgroups (P1 and P2). Subgroup P1, comprising 52 subjects, received periodontal treatment first, followed by tongue cleaning. Subgroup P2, comprising 59 subjects, received tongue cleaning first, followed by periodontal treatment. Subjects in the gingivitis group were also randomly assigned into two subgroups (G1 and G2). Subgroup G1, comprising 58 subjects, received periodontal treatment first, followed by tongue cleaning. Subgroup G2, comprising 60 subjects, received tongue cleaning first, followed by periodontal treatment.

After completing each treatment, the same oral malodor measurement and oral examinations were conducted. The final number of subjects who completed the treatments (treatment 1 and treatment 2) was 51 subjects (27 men and 24 women, mean age 46.2 ± 7.6 years) in P1, 51 subjects (26 men and 25 women, mean age 44.7 ± 8.3 years) in P2, 58 subjects (27 men and 31 women, mean age 39.8 ± 8.2 years) in G1, and 58 subjects (25 men and 33 women, mean age 39.9 ± 8.3 years) in G2.

Periodontal treatment

The periodontitis group received nonsurgical therapy, including oral hygiene instruction (tooth brushing and interproximal cleaning), scaling, tooth polishing, root planing and/or removal of ill-fitting prostheses. Subjects were reassessed 1 wk after the completion of periodontitis treatment.

The gingivitis group received oral hygiene instruction (tooth brushing and interproximal cleaning), scaling and tooth polishing. Subjects were reassessed 1 wk after the completion of gingivitis treatment.

The length of periodontal treatment depended on the severity of the periodontal condition of the subjects.

Tongue cleaning

Tongue cleaning consisted of provision of information about tongue coating and oral malodor, and instruction on the tongue cleaning method and tongue coating self-check. Subjects were instructed to clean their tongue from the terminal sulcus to the front using a soft, small-headed toothbrush with gentle force and strokes (37). They were advised to clean their tongue before tooth brushing (37) every

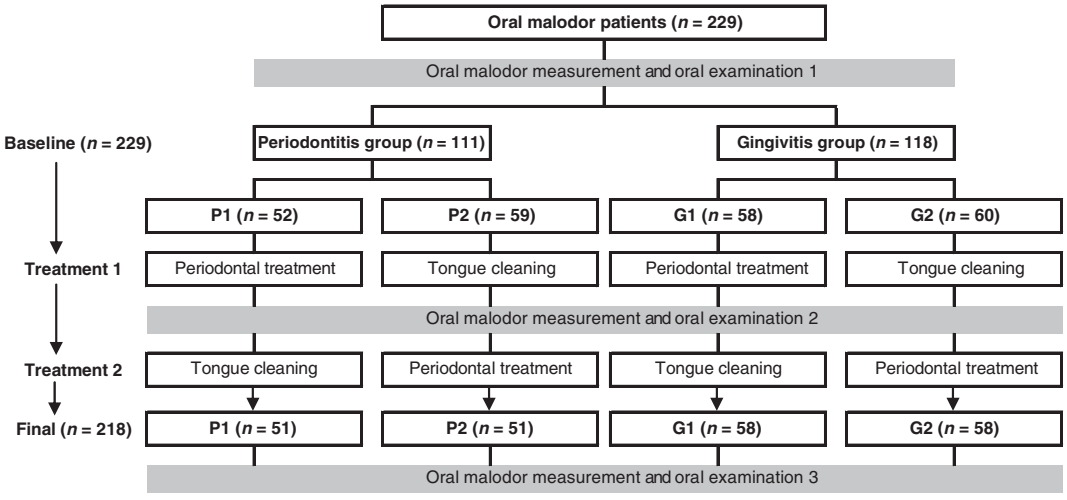

Fig. 1. Flow chart of oral malodor treatment.

morning for 7 d at home and self-check tongue coating with a mirror during tongue cleaning. On the 8th day after tongue cleaning instruction, oral malodor assessment and oral examinations were conducted.

Statistical analysis

The chi-square test was used to detect the distributional differences in sex, and Student's unpaired *t*-test was used to examine the statistical differences in mean age between the groups. Student's unpaired *t*-test was also used to determine the differences in the mean values of organoleptic score, H_2S, CH_3SH, periodontal parameters (number of teeth with bleeding on probing, gingival index, number of teeth with deep pockets, pocket depth and clinical attachment level), plaque index, tongue coating score and BANA test score between the periodontitis and gingivitis groups. The Student's paired *t*-test was used to examine the changes in the mean values of organoleptic score, H_2S, CH_3SH and periodontal parameters, plaque index, tongue coating score and BANA test score at the different assessments in each subgroup. The statistical analysis was performed with the SPSS 17.0 software (SPSS Japan, Tokyo, Japan). The level of significance was set at $p < 0.05$.

Results

Characteristics of the subjects

The subjects in the periodontitis group (53 men and 49 women, mean age 45.4 ± 8.0 years) were significantly older than those in the gingivitis group (52 men and 64 women, mean age 39.8 ± 8.2 years). However, a significant distributional difference in sex was not detected between two groups. The mean numbers of teeth present in the periodontitis group (23.8 ± 4.8) was significantly lower compared with the gingivitis group (26.5 ± 2.7; $p < 0.01$). There was no significant difference in age or sex between P1 and P2 or between G1 and G2. Questionnaire data revealed that all the subjects brushed their teeth every morning. Almost 18% of those (17.5%) cleaned their tongue every day after morning tooth brushing. Regarding smoking behavior, about one-third (32.1%) of subjects were current smokers, 9.2% were past smokers and 58.7% were nonsmokers.

Oral malodor and oral health status at the baseline

The periodontitis group had significantly higher mean values of organoleptic score, H_2S, CH_3SH, periodontal parameters (number of teeth with bleeding on probing, gingival index, pocket depth and clinical attachment level), plaque index and tongue coating scores than the gingivitis group ($p < 0.01$). However, the BANA test did not show a significant difference between the groups ($p = 0.186$; Table 1).

Chronological changes in periodontal parameters and oral hygiene status

Periodontitis group— At baseline, no statistically significant differences were observed in the mean values of periodontal parameters, plaque index, tongue coating score and BANA test score between P1 and P2 (Table 2). However, all periodontal parameters showed statistically significant improvements after periodontal treatment and tongue cleaning ($p < 0.05$), except in P1 from treatment 1 to treatment 2 (for number of teeth with deep pockets) and in P2 from baseline to treatment 1 (for number of teeth with deep pockets and clinical attachment level). There were statistically significant reductions in plaque index, tongue coating score and BANA test score in both P1 and P2 after periodontal treatment and tongue cleaning ($p < 0.01$).

Gingivitis group— At baseline, no statistically significant differences were detected in the mean values of periodontal parameters, plaque index, tongue coating score and BANA test score between G1 and G2 (Table 2). Moreover, all periodontal parameters showed statistically significant improvements after periodontal treatment and tongue cleaning ($p < 0.01$), except in G1 and in G2 from treatment 1 to treatment 2 (for clinical attachment level) and in G2 from baseline to treatment 1 (for number of teeth with bleeding on probing and clinical attachment level). Significant reductions in plaque index, tongue coating score and BANA test score were also found after periodontal treatment and tongue cleaning. However, statistically significant differences were not detected from the baseline to treatment 1 (for tongue coating) and from treatment 1 to treatment 2 (for plaque index) in G1; and from treatment 1 to treatment 2 (for tongue coating and BANA test) in G2.

Chronological changes in oral malodor parameters

Periodontitis group— At baseline, there were no statistically significant differences in the mean values of organoleptic score, H_2S and CH_3SH between P1 and P2. However, a significant

Table 1. Oral malodor and oral health status at baseline

Variable	Periodontitis group	Gingivitis group	*p*-Value
Organoleptic score	2.84 ± 0.67	2.29 ± 0.46	< 0.001
H_2S	7.40 ± 4.52	5.51 ± 4.57	0.003
CH_3SH	8.80 ± 5.13	2.92 ± 2.70	< 0.001
Number of teeth with bleeding on probing	10.75 ± 3.00	4.95 ± 2.17	< 0.001
Gingival index	1.84 ± 0.38	0.81 ± 0.51	< 0.001
Number of teeth with deep pockets	6.12 ± 2.55	NA	NA
Pocket depth	4.17 ± 0.42	2.46 ± 0.50	< 0.001
Clinical attachment level	4.29 ± 0.44	2.56 ± 0.43	< 0.001
Plaque index	3.01 ± 0.37	1.53 ± 0.51	< 0.001
Tongue coating	11.24 ± 3.91	8.05 ± 3.39	< 0.001
BANA test score	1.51 ± 0.64	1.40 ± 0.62	0.186

Data are presented as the means ± SD. NA, not aplicable.

Table 2. Chronological changes in periodontal parameters and oral hygiene status

Variable	Group	Baseline	*p*-Value*	Treatment 1	*p*-Value†	Treatment 2
Number of teeth with bleeding on probing	P1	10.45 ± 2.67	< 0.001	3.55 ± 0.64	< 0.001	3.27 ± 0.49
	P2	11.06 ± 3.30	< 0.001	9.96 ± 2.62	< 0.001	3.73 ± 0.67
	G1	4.83 ± 2.18	< 0.001	1.67 ± 0.80	< 0.001	1.47 ± 0.71
	G2	5.07 ± 2.18	0.146	4.93 ± 1.95	< 0.001	1.57 ± 0.73
Gingival index	P1	1.81 ± 0.44	< 0.001	0.36 ± 0.09	< 0.001	0.33 ± 0.08
	P2	1.86 ± 0.31	< 0.001	1.30 ± 0.22	< 0.001	0.33 ± 0.06
	G1	0.81 ± 0.51	< 0.001	0.16 ± 0.10	< 0.001	0.13 ± 0.07
	G2	0.82 ± 0.51	< 0.001	0.61 ± 0.41	< 0.001	0.13 ± 0.06
Number of teeth with deep pockets	P1	5.88 ± 2.37	< 0.001	0.90 ± 1.30	0.569	0.88 ± 1.31
	P2	6.35 ± 2.73	0.224	6.47 ± 2.98	< 0.001	1.04 ± 0.96
	G1	NA	NA	NA	NA	NA
	G2	NA	NA	NA	NA	NA
Pocket depth	P1	4.10 ± 0.34	< 0.001	2.97 ± 0.46	< 0.001	2.79 ± 0.31
	P2	4.25 ± 0.48	0.017	4.15 ± 0.57	< 0.001	3.15 ± 0.36
	G1	2.42 ± 0.48	0.001	2.35 ± 0.38	< 0.001	2.31 ± 0.35
	G2	2.50 ± 0.52	< 0.001	2.44 ± 0.44	0.004	2.38 ± 0.36
Clinical attachment level	P1	4.21 ± 0.30	< 0.001	3.08 ± 0.46	0.018	2.96 ± 0.24
	P2	4.38 ± 0.52	0.737	4.38 ± 0.53	< 0.001	3.23 ± 0.48
	G1	2.54 ± 0.40	< 0.001	2.42 ± 0.37	0.742	2.42 ± 0.33
	G2	2.58 ± 0.45	0.641	2.59 ± 0.42	0.120	2.56 ± 0.39
Plaque index	P1	2.99 ± 0.38	< 0.001	0.60 ± 0.08	< 0.001	0.45 ± 0.06
	P2	3.02 ± 0.37	< 0.001	2.01 ± 0.28	< 0.001	0.46 ± 0.06
	G1	1.58 ± 0.54	< 0.001	0.32 ± 0.11	0.052	0.27 ± 0.11
	G2	1.47 ± 0.49	< 0.001	0.58 ± 0.20	< 0.001	0.28 ± 0.09
Tongue coating	P1	10.67 ± 4.32	< 0.001	7.78 ± 3.12	< 0.001	1.63 ± 0.75
	P2	11.80 ± 3.42	< 0.001	2.69 ± 0.51	< 0.001	1.73 ± 0.49
	G1	7.89 ± 3.30	< 0.001	7.12 ± 2.96	< 0.001	1.62 ± 0.62
	G2	8.21 ± 3.49	< 0.001	1.60 ± 0.56	0.303	1.50 ± 0.54
BANA test score	P1	1.47 ± 0.70	< 0.001	1.10 ± 0.76	< 0.001	0.29 ± 0.46
	P2	1.55 ± 0.58	< 0.001	0.55 ± 0.50	< 0.001	0.31 ± 0.47
	G1	1.31 ± 0.65	0.204	1.21 ± 0.74	< 0.001	0.22 ± 0.46
	G2	1.48 ± 0.57	< 0.001	0.43 ± 0.53	0.118	0.28 ± 0.56

Data are presented as the means ± SD. NA, not applicable. * Treatment 1 vs. baseline. † Treatment 2 vs. treatment 1.

reduction in organoleptic score, H_2S and CH_3SH was observed at treatment 1 compared with the baseline in both groups ($p < 0.01$). The greater reductions were found in P1 (organoleptic score 2.86–1.45, H_2S 7.18–2.50 and CH_3SH 8.67–1.80) than in P2 (organoleptic score 2.82–2.61, H_2S 7.63–4.88 and CH_3SH 8.92–5.99; $p < 0.01$). At treatment 2, oral malodor parameters further decreased significantly in P1 (organoleptic score 1.45–0.96, H_2S 2.50–1.02 and CH_3SH 1.80–0.26) and in P2 (organoleptic score 2.61–0.94, H_2S 4.88–1.13 and CH_3SH 5.99–0.27; $p < 0.01$; Fig. 2A).

Gingivitis group— At baseline, there were no statistically significant differences in the mean values of organoleptic score, H_2S and CH_3SH between G1 and G2. In contrast, a significant reduction in organoleptic score, H_2S and CH_3SH was found at treatment 1 compared with the baseline in both groups ($p < 0.01$). Greater reductions were found in G2 (organoleptic score 2.33–1.21, H_2S 5.62–1.10 and CH_3SH 3.00–0.41) than in G1 (organoleptic score 2.26–1.98, H_2S 5.42–4.32 and CH_3SH 2.84–2.08; $p < 0.01$). At treatment 2, oral malodor parameters further decreased significantly in G2 (organoleptic score 1.21–0.80, H_2S 1.10–0.72 and CH_3SH 0.41–0.19) and in G1 (organoleptic score 1.98–0.83, H_2S 4.32–0.79 and CH_3SH 2.08–0.26; $p < 0.01$; Fig. 2B).

Discussion

The results from this randomized controlled study demonstrated the beneficial impacts of periodontal treatment and tongue cleaning on oral malodor in patients affected by periodontal diseases; however, the degrees of improvement were different between the periodontitis and gingivitis groups. Periodontal treatment resulted in more marked improvement of oral malodor than tongue cleaning in periodontitis patients, while tongue cleaning alone achieved oral malodor improvement more successfully in gingivitis patients. The different oral health condition at the baseline yielded the different outcome from each treatment in this study. It is probably because the main cause of oral malodor may be different. These findings could be partly supported by the study of Miyazaki *et al.* (3), who suggested that oral malodor might be caused mainly by tongue coating in the younger generation and by periodontal disease together with tongue coating in the older generation.

Our data showed significantly higher values of oral malodor parameters and tongue coating score in the periodontitis group than the gingivitis group.

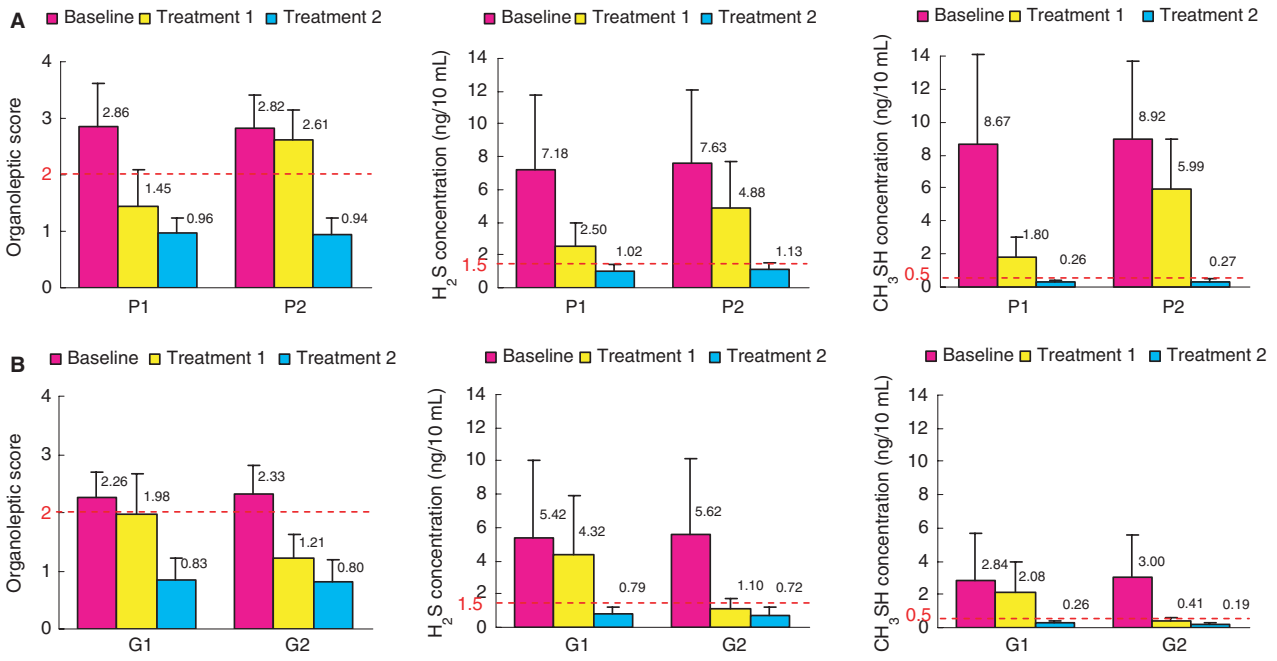

Fig. 2. Chronological changes in oral malodor parameters in the periodontitis group (A) and in the gingivitis group (B). All mean differences are significant at $p < 0.01$.

This finding is in agreement with the studies of Yaegaki & Sanada, who found a considerably higher concentration of volatile sulfur compounds and a greater tongue coating in periodontitis patients than in healthy subjects (9,38). Several clinical studies report the positive correlation between oral malodor and the severity of the periodontal disease (4,9,39,40), because populations of volatile sulfur compound-producing organisms are larger in periodontal pockets than in the normal gingival sulcus (7). In addition, we found that patients in the periodontitis group had significantly higher methyl mercaptan vs. hydrogen sulfide, whereas hydrogen sulfide was significantly higher vs. methyl mercaptan in the gingivitis group. This finding supported previous clinical studies demonstrating that the methyl mercaptan/hydrogen sulfide ratio increased with the severity of periodontal disease and that methyl mercaptan was the main component of the volatile sulfur compounds in periodontitis patients (9,38). Yaegaki & Sanada (9,38) also demonstrated a greater contribution of the tongue coating to formation of volatile sulfur compounds in periodontitis patients than in healthy subjects. In our results, however, the BANA test of the tongue coating sample did not show a statistically significant difference between the periodontitis and gingivitis groups. This could be due to the fact that the BANA-positive reactions are caused by *P. gingivalis*, *T. denticola* and *T. forsythia*, and the tongue coating in periodontitis patients harbors and promotes many kinds of volatile sulfur compound-producing bacteria other than the BANA-hydrolyzing bacterial species.

We found significant reductions of the tongue coating score and the BANA test score in the periodontitis group after periodontal treatment. This demonstrated that periodontal treatment itself yielded a significant decrease in tongue coating accumulation and species that produce trypsin-like protease activity in the tongue coating of periodontitis patients. The present results support findings of previous studies showing that the volume of tongue coating tends to increase during periodontal disease, and suggests that the improvement in oral malodor after periodontal treatment derived in part from the decrease of microflora in the tongue coating.

In the present study, tongue coating status was clearly affected by tongue cleaning, as demonstrated by the significant reductions of the mean tongue coating score and BANA test score in all groups. The study subjects were specifically instructed to brush the posterior segment of the tongue dorsum and self-check the tongue coating during cleaning. They were also told to remember that the posterior of the tongue was least accessible and usually smelled worst (41,42). This tongue cleaning instruction was considered to achieve the optimal effect on tongue coating reduction. As questionnaire data showed, most of subjects did not have appropriate tongue cleaning behavior nor knowledge of about the tongue coating. However, daily tongue brushing and self-checking of the tongue coating could decrease tongue coating accumulation and bacterial levels on dorsum of the tongue along with a concomitant reduction in oral malodor. Hence, the self-awareness of the tongue coating and its relationship with oral malodor should receive better attention, not only by patients but also by dental professionals.

This study indicated that both periodontal treatment and tongue cleaning

were effective to reduce oral malodor in the periodontitis group. Although periodontal treatment resulted in greater oral malodor reduction than tongue cleaning, the patients would not receive the full benefit without tongue cleaning. Thus, the ideal protocol on oral malodor treatment for periodontitis patients requires a combination of primary periodontal treatment and supplementary tongue cleaning. Such findings conflict with the previous randomized trial by Quirynen *et al*. (43), which reported that periodontal treatment and tongue cleaning had only a weak impact on the level of volatile sulfur compounds in patients with moderate periodontitis, except when combined with a mouth rinse. The different results may be due to the selection criteria of the subject population. Indeed, Quirynen *et al*. selected periodontitis patients without obvious tongue coating, while we did not set any criteria for tongue coating status of the subjects at the time of recruitment.

Our study also showed that periodontal treatment and tongue cleaning impacted on oral malodor reduction in the gingivitis group. However, the effect of periodontal treatment was limited, whereas tongue cleaning alone led to a great reduction of oral malodor. After tongue cleaning, the organoleptic score, H_2S and CH_3SH were almost below the threshold levels of oral malodor. The present results indicated that tongue cleaning alone was the most effective approach to reduce oral malodor in the gingivitis patients. Previous studies also reported that tongue cleaning markedly reduced volatile sulfur compounds, not only in patients with periodontal disease but also in healthy subjects (9,23,44,45). These findings are consistent with the idea that the dorsum of the tongue is a primary source of oral malodor and suggest that the incorporation of tongue brushing into the daily toothbrushing routine is important in managing oral malodor.

Oral malodor is a multifactorial disease that requires a well-defined diagnosis and treatment. Identification of the causative factors and institution of proper measurement is essential to propose the appropriate treatment modality (46). In the present study, subjects presented with advanced periodontal diseases and obvious tongue coating, and these conditions were implicated as the causes of oral pathological malodor. In view of this clinical background, the study subjects received treatments such as periodontal treatment and oral hygiene instruction. As a result, their oral malodor dramatically improved.

The treatment of periodontal disease and tongue cleaning, which can control bacterial plaque growth and progression, are highly dependent on the patient's daily practice of oral hygiene. Likewise, the treatment of oral malodor is highly dependent on personal habits of oral hygiene. Based on the facts and the present results, it is possible to propose an appropriate treatment protocol for oral malodor patients with periodontal diseases and highlight the importance of personal oral care for managing oral malodor. In addition, education about the causes of oral malodor, prevention and lessening the accumulation of oral bacteria is necessary to successfully improve oral malodor, not only at the individual level but also at the community level.

This study has some limitations. We have not measured the quantity of tongue coating. Instead, the thickness of the tongue coating was evaluated and scored visually in each of nine sections of the tongue dorsum. Therefore, the meaning and reliability of the 'tongue-coat' measurement were still not fully determined. Besides, although the same procedure was employed to take each tongue coating sample for the BANA test, the amount of tongue coating scrape samples was not quantitative. Our study investigated only the short-term effects of periodontal treatment and tongue cleaning on oral malodor treatment. Furthermore, a different population and/or different oral conditions may have the different outcomes. Future research involving the long-term evaluation of oral malodor-related outcomes in different types of populations are needed. In spite of these limitations, the present study could provide important information to formulate treatment strategies for periodontal patients with oral malodor.

Conclusion

Periodontal treatment and tongue cleaning both impacted on oral malodor reduction; however, the degrees of effects were different depending on periodontal status. Periodontal treatment resulted in more significant improvement of oral malodor than tongue cleaning in the periodontitis group, while tongue cleaning alone achieved oral malodor improvement more successfully in the gingivitis group. These findings suggested that periodontal treatments played an important role and that tongue cleaning contributed to a lesser extent to oral malodor reductions in periodontitis patients. In contrast, tongue cleaning alone can be the most effective approach to reduce oral malodor in gingivitis patients.

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