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ORIGINAL ARTICLE

Effect of non-surgical periodontal treatment by full-mouth disinfection or scaling and root planing per quadrant in halitosis—a randomized controlled clinical trial

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Abstract
Objective The objective of this study was to compare the effect of one-stage full-mouth disinfection (FMD) and conventional quadrant scaling in four weekly sessions (QS) on periodontal clinical parameters and halitosis among individuals with advanced chronic periodontitis.
Materials and methods In this randomized controlled clinical trial, 30 individuals were divided into two groups: FMD (n = 15) and QS (n = 15). The following data were collected at the baseline and 90 days after treatment: plaque index, tongue-coating index (TCI), bleeding on probing, probing depth, and clinical attachment level. Halimetry was performed by the organoleptic method, and the levels of volatile sulfur compounds (H2S and CH3SH) were measured by gas chromatography. The Chi-square, Fisher's exact, the Mann-Whitney, the McNemar, and the Wilcoxon tests were used for statistical analysis.
Results Both groups showed statistically significant improvements in periodontal clinical parameters, reduction in TCI, organoleptic scores, and in CH_3SH levels between times. However, major reduction was observed in FMD group.
Conclusion Non-surgical periodontal therapy, regardless of the protocol, was effective in improving periodontal clinical status of individuals, decreasing organoleptic scores and CH_3SH levels between times, as well as reducing halitosis.
Clinical relevance This study contributed to the knowledge that non-surgical periodontal therapy, whether by FMD or QS, was effective in reducing halitosis in individuals with advanced chronic periodontitis.

Keywords Halitosis · Intra-oral malodor · Halitosis · Periodontitis · Sulfur compounds · Periodontal treatment

Introduction

Periodontal diseases are recognized as infectious inflammatory processes associated with subgingival microorganisms, mediated by the host's immune-inflammatory response, causing loss of tooth support. In its advanced stages, clinical signs and symptoms may include swollen and bleeding gums, suppuration, tooth mobility, tooth migration, and halitosis [1, 2].

Halitosis, or oral malodor, is an unpleasant odor emanating from the oral cavity and, in most cases, is the result of the metabolism of the oral microbiota, with possible intra-oral and extra-oral etiology [3]. Halitosis affects most of the adult population (around 25 %), causing social embarrassment and discomfort for both individuals with this condition and people around them, triggering low self-esteem, and affecting the individual's interpersonal relationships and quality of life [3, 4].

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The etiology of extra-oral halitosis includes conditions involving the gastrointestinal tract, the upper and lower respiratory system, the use of medications, diabetes mellitus, liver cirrhosis, uremia, and idiopathic conditions, while the intra-oral etiology is mainly associated with the presence of periodontal diseases and tongue coating [5, 6].

For the most part, halitosis results from the production of volatile sulfur compounds (VSCs) by bacteria in the saliva, tongue-coating biofilms, and periodontal pockets. The main VSCs responsible for halitosis are methyl mercaptan (CH_3SH), hydrogen sulfide (H2S), and dimethyl sulfide [$(CH_3)_2SH$] [5, 7]. Several bacterial species can produce H_2S, while CH_3SH production, especially at high levels, is mainly related to periodontal pathogens [8, 9].

The most frequently used method, and still considered the gold standard for assessing halitosis, is the organoleptic method [3, 8, 9], i.e., perceiving the odor emanated by the individual, whereas VSCs can be measured with sulfide monitors or through quantitative and qualitative analyses by gas chromatography [10, 11] which are considered the most sensitive and objective methods to assess these compounds [12].

Periodontal treatment, consisting of scaling and root planing procedures, is performed conventionally by quadrant scaling in four weekly sessions (QS). The approach of one-stage full-mouth disinfection (FMD) performs the scaling and root planing procedures in a 24-h period, combined with the use of chlorhexidine (CHX) for up to 15 days, promoting rapid disinfection of the mucous membranes, tongue, and tonsils in order to avoid reinfection of sites already treated for pathogens that reside in other locations [13–15].

Studies have suggested that non-surgical periodontal treatments, when associated with adequate plaque control, tongue cleaning, and the use of local antimicrobial agents, are effective methods to control halitosis [9, 16]; moreover, halitosis is one of the primary complaints and reasons for seeking periodontal therapy [3].

In this regard, the present study hypothesized that the FMD protocol, when compared to the QS procedure, could have a greater effect in reducing VSC levels and halitosis. Thus, the objective of this randomized clinical trial was to evaluate the effect of FMD and QS non-surgical periodontal treatments on the VSC levels and halitosis in patients with advanced chronic periodontitis.

Material and methods

Study population

The sample comprised individuals with a diagnosis of advanced chronic periodontitis, who were referred for treatment in the Pontific Catholic University of Minas Gerais, Brazil. This study was approved by the Ethics Committee (#30378613.5.0000.5149) and registered at Clinicaltrials.gov (NTC02368678). Written informed consent was obtained from each study participant after all procedures had been fully explained.

The following inclusion criteria were used: age between 35 and 60 years, presence of at least 20 natural teeth, diagnosis of advanced chronic periodontitis [17], and self-reported complaints of halitosis. Subjects who had at least one of the following conditions were excluded from the study: current (lifetime consumption of ≥100 cigarettes and smoked at the time of examination) or former smokers (lifetime consumption of ≥100 cigarettes and did not smoke at the time of examination) [18], diabetes [19] and/or immunological disorders, known gastrointestinal and respiratory conditions associated with halitosis, pregnant or lactating women, patients with removable partial dentures and/or fixed or removable orthodontic appliances, need for the use of prophylactic antibiotics to perform the treatment, regular use or in the last 6 months of any kind of mouthwashes, and periodontal treatment in the 6 months prior to the start of the study.

Sample size was determined with an expected mean VSC for CH_3SH (parts per billion; ppb) difference of 6 (20 % difference based on a mean CH_3SH of 25), a standard deviation of 5, a 95 % confidence interval, and a power of 80 % from a pilot study previously conducted. The results indicated that 12 subjects in each group were required for the study and 15 in each group would be safe when considering subject dropouts. Level of VSCs was considered the primary outcome in this study, while probing depth (PD) reduction and clinical attachment level (CAL) gain after non-surgical periodontal treatment secondary outcome.

Thus, 30 eligible individuals with advanced chronic periodontitis were selected from April 2013 to May 2014, according to the inclusion and exclusion criteria. The selection of this initial convenience sample was carried out by randomization process (simple drawing): 30 envelopes containing the identification of the two treatment groups (FMD and QS) were shuffled and sequentially numbered. For every two eligible participants, an envelope was drawn for each treatment group until the two groups had been filled:

(1) FMD group (n = 15), in which individuals were submitted to periodontal treatment by the one-stage full-mouth disinfection, i.e., full-mouth scaling and root planing procedures within 24 h in two sessions, 60 min each session, for two consecutive days, including subgingival irrigation with 1 % CHX gel after scaling, tongue brushing with 1 % CHX gel for 1 min, and mouthwashes with 0.12 % CHX for 30 s at the beginning and at the end of each session, with the last 10 s involving gargling. Furthermore, a daily 0.12 % CHX mouthwash (twice a day) was performed for 2 weeks [13].

(2) QS group (n = 15), in which individuals were submitted to periodontal treatment by the scaling and root planing procedures, performed by conventional quadrant scaling in four sessions of 30 min. Each on a weekly basis, tongue brushing

with 1 % CHX gel for 1 min and mouthwashes with 0.12 % CHX for 30 s at the beginning and at the end of each session, with the last 10 s involving gargling.

Periodontal examination

A full-mouth periodontal examination was conducted to assess the following clinical parameters at four sites per tooth: probing depth (PD), clinical attachment level (CAL), and bleeding on probing (BOP). Plaque index (PI) [20] and tongue-coating index (TCI) [21] were also assessed. Advanced chronic periodontitis was determined by the presence of at least one site with PD > 6 mm and CAL > 4 mm in the same site [17].

Participants were evaluated (periodontal examination and halimetry) in two stages: prior to non-surgical periodontal treatment (T1) and 90 days after treatment (T2). Periodontal examinations were performed by a single-trained examiner (BCD) who was blinded to individual's treatment group. Instructions on oral hygiene methods for all participants in both groups, including brushing the back of the tongue, air polishing, and assessment of PI and TCI, were provided by another researcher (JOS).

A pilot study was conducted with five individuals in each treatment group in order to train the researchers on how to conduct periodontal clinical examinations, halitosis measurements, and periodontal treatment. It is important to note that these individuals were not used in the final study. Initial PD and CAL measurements obtained during the pilot study were recorded and repeated within 1 week and then again 90 days after periodontal treatment. These data were analyzed using the Kappa test, and intra-examiner results showed satisfactory values greater than 0.82 for PD and CAL, as well as a weighted Kappa test for the organoleptic method of 0.84.

Two experienced, trained periodontists (AMSDO and JOS) carried out the mechanical debridement procedures of the two treatment protocols with manual Gracey and McCall curettes, as well as ultrasonic devices.

Halimetry

Halitosis assessment was performed through two methods: (1) the organoleptic method and (2) the measurement of VSC levels, including H_2S and CH_3SH. Participants were instructed to avoid spicy food containing ingredients such as garlic, onions, and peppers, as well as alcoholic drinks and mouthwashes 2 days prior to halimetry. On the day of the examination, individuals were instructed to avoid coffee, candies, chewing gums, or breath mints, as well as perfumes, deodorants, shampoos, creams, and scented moisturizers. They were also advised to have breakfast at least 2 h and no more than 4 h before the examination.

Organoleptic assessment

Participants were instructed to keep their mouth closed, breathing only through the nose for 3 min. Afterwards, they were told to exhale slowly through their mouth at a distance of 10 cm from the nose of the examiner (JOS). Breath odor intensity was then recorded on a five-point scale, as suggested by Rosenberg et al. [22, 23] where: 0 = no appreciable odor, 1 = barely noticeable odor, 2 = slight but noticeable odor, 3 = moderate odor, 4 = strong odor, and 5 = extremely foul odor.

CSV measurement

The gas chromatograph equipment OralChroma™ (Abilit Corporation, Osaka, Japan), that is able to detect and measure the concentration in parts per billion (ppb) of H_2S and CH_3SH in a volume of 0.5 ml of intra-oral air, was used according to manufacturer's instructions [12].

The OralChroma™ digitally displays the concentrations of H_2S and CH_3SH in nanograms/10 ml and ppb. According to the manufacturer, the perception thresholds for H_2S and CH_3SH gases are 112 ppb and 26 ppb, respectively. In the present study, values equal to or greater than these values were considered high [12]. Every chromatogram was visually reviewed before the results were accepted [5, 12].

Reassessment of clinical periodontal parameters and halimetry were repeated 90 days after the end of periodontal treatment (T2). All individuals with PD ≥ 4 mm with BOP and/or suppuration underwent a new surgical or non-surgical periodontal treatment as needed.

A flowchart of the study design from screening to completion of the 90-days of the study, according to the Consolidated Standards of Reporting Trials (CONSORT), is shown in Fig. 1.

Statistical analysis

Fisher's exact and the Mann-Whitney tests were used to verify the homogeneity of the groups in relation to variables of interest. Intra-group comparisons (T1 versus T2) and inter-group comparisons (FMD versus QS) in relation to halimetry methods, periodontal parameters and TCI, were performed through the Mann-Whitney, Chi-squared, Fisher exact, Wilcoxon, and McNemar tests when appropriate. The software package SPSS version 17.0 for Windows (Chicago, IL, USA) was used. All results were considered significant at $p < 0.05$.

Results

Table 1 shows characteristics of the sample with respect to demographic variables. FMD and QS groups were homogeneous in relation to age, gender, and educational level.

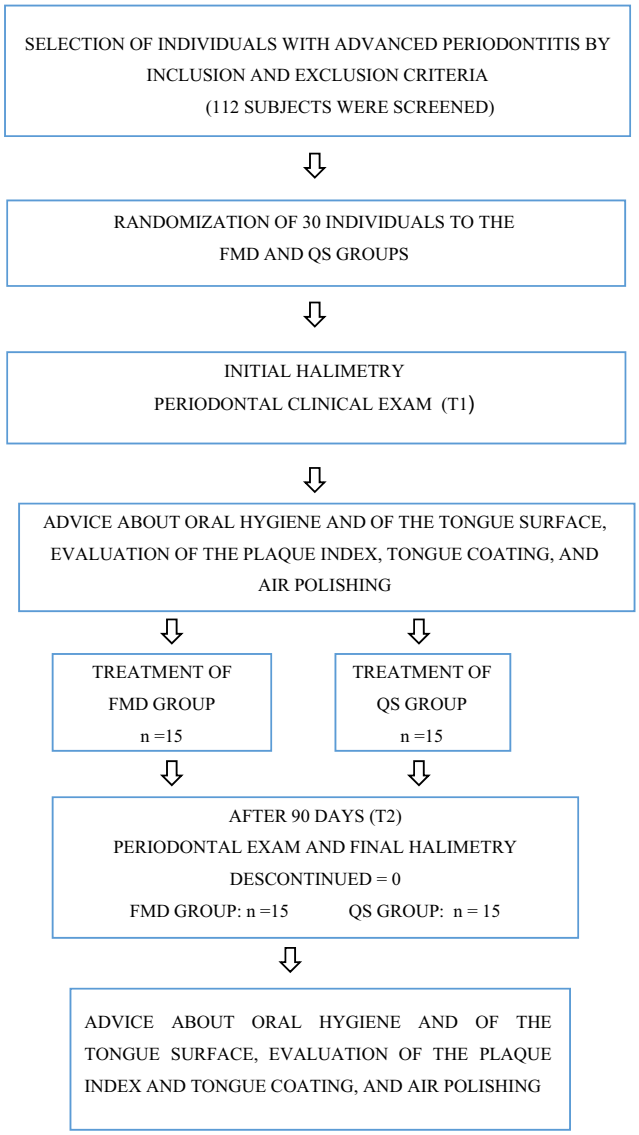

Fig. 1 Study design from screening to completion of the 90-day study according to the Consolidated Standards of Reporting Trials (CONSORT)

In Table 2, no significant reductions were observed in H_2S between the groups and examination times. When groups were compared in relation to the organoleptic method (FDM from 3.75 to 1:47, $p < 0.001$; QS from 3.89 to 2.10, $p = 0.019$) and CH_3SH levels (FMD from 25.42 to 0.83, $p < 0.001$; QS from 26.31 to 1:47, $p = 0.003$), a significant reduction were identified in both groups between T1 and T2. It should be noted that the FMD group showed a greater reduction when compared to the QS group. Moreover, the organoleptic method and CH_3SH levels were significantly different between FMD and QS groups at T2. The categorical assessment of $CH_3SH \geq 26$ ppb also showed reduction in both groups between T1 and T2.

The comparison between the FMD and QS groups at T1 showed no significant differences in relation to any periodontal clinical parameters, TCI, and number of teeth, showing sample homogeneity with respect to the initial periodontal condition. Between T1 and T2, there was a significant reduction in BOP, as well as an increase in the percentage of sites with PD <4 mm, a reduction in the percentage of sites with PD of 4–6 and >6 mm, CAL, and TCI, demonstrating an effectiveness of non-surgical periodontal treatment, regardless of treatment modality (Table 3).

Discussion

Periodontitis, as a chronic inflammatory infectious process, has been recognized as one of the main factors associated with the origin of intra-oral halitosis [6, 24, 25]. Halitosis has been extensively correlated with levels of VSCs (H_2S and CH_3SH) generated in the oral cavity by gram-negative anaerobic bacteria that colonize periodontal tissues [26–28] and the back of the tongue [28–30]. These gases are considered the major components of mouth odor, being that CH_3SH usually has a greater influence on halitosis than H_2S [4].

After the proposal of the FMD protocol, the literature has presented conflicting data regarding the best protocol of choice for non-surgical periodontal therapy and the true role of adjuvants. Many studies have shown better clinical and microbial results with the FDM protocol [2, 13, 31]; some of

Table 1 Characterization of the sample

Variables		Groups				*p* value
		FMD		QS		
Gender	Female	10	66.7 %	12	80.0 %	0.409*
	Male	5	33.3 %	3	20.0 %	
Educational level	≤8 years	3	20.0 %	7	46.7 %	0.241*
	8–12 years	9	60.0 %	7	46.7 %	
	≥12 years	3	20.0 %	1	6.7 %	
Age		48.13	(±7.78)	47.00	(±8.67)	0.648**

*The Fisher exact test

**The Mann-Whitney test

Table 2 Intra- and inter-group comparisons for the organoleptic method and VSC measurements (H_2S and CH_3SH)

	Groups	T1	T2	*p**
Organoleptic method	FMD	3.75	1.47	<0.001
	QS	3.89	2.10	0.019
	*p***	0.169	0.041	
H_2S (ppb)	FMD	7.24	8.07	0.527
	QS	6.49	6.17	0.710
	*p***	0.157	0.264	
$H_2S \geq 112$ ppb (%)	FMD	87.9	82.3	0.089
	QS	86.6	80.4	0.076
	*p***	0.414	0.651	
CH_3SH (ppb)	FMD	25.42	0.83	<0.001
	QS	26.31	1.47	0.003
	*p***	0.079	0.023	
$CH_3SH \geq 26$ ppb (%)	FMD	16.7	0.0	***
	QS	14.5	0.0	***
	*p***	0.613	***	

*Intra-group comparisons through the McNemar and Wilcoxon tests, when appropriate

**Inter-group comparisons through the Chi-squared or Fisher exact, and the Mann-Whitney tests, when appropriate

****p* value not computed

them partially assigning their success to the short time period of debridement completion, whereas others attribute success to the intensive and continuous use of CHX. However, a literature review failed to observe superior results for the FMD protocol [2]. Furthermore, studies have shown additional benefits of the FMD protocol, such as greater adherence, low cost, fewer treatment sessions, with less traveling or absence from work for the patient [2, 13, 31]. Modest additional clinical benefits of the FMD protocol over QS were demonstrated in a recent systematic review and meta-analysis [32].

Our results showed that non-surgical periodontal therapy significantly improved similar clinical periodontal parameters when performed by QS or FMD. These findings are consistent with several studies that compared the effectiveness of these two periodontal treatment strategies and reported no significant differences between them in relation to clinical periodontal parameters [31, 33, 34].

In the present study design, two factors differ between groups: the full-mouth treatment and the CHX continuous use. Hence, it was hypothesized that the FMD protocol due to a rapid and complete disinfection of the mouth, added to the intense and continuous use of CHX (daily use the 0.12 % CHX mouthwash performed for 2 weeks), could provide a greater effect in reducing VSC levels and halitosis when compared to QS. However, both forms of non-surgical periodontal therapy were effective in reducing scores in the organoleptic method and CH_3SH levels, despite a greater reduction has occurred in the FMD group. These factors, separately or together, may have contributed to these results. Future studies comparing FMD, full-mouth scaling, and QS with or without

Table 3 Intra- and inter-groups comparisons of periodontal parameters and tongue-coating index

		Groups	T1	T2	*p**
Number of teeth (mean ± SD)		FMD	25.26 (±2.02)	25.26 (±2.02)	1.000
		QS	23.67 (±3.86)	23.67 (±3.86)	1.000
CAL [mm (mean ± SD)]		FMD	2.96 (±0.81)	2.09 (±0.77)	0.023
		QS	3.10 (±1.05)	2.35 (±1.01)	0.039
Percentage of sites with CAL ≥ 4 mm		FMD	37.5 %	21.4 %	0.012
		QS	32.4 %	26.7 %	0.024
TCI (mean ± SD)		FMD	0.58 (±0.31)	0.24 (±0.28)	0.014
		QS	0.60 (±0.31)	0.26 (±0.36)	0.021
PD (mean ± SD)		FMD	2.49 (±0.16)	2.33 (±0.12)	0.032
		QS	2.49 (±0.15)	2.37 (±0.11)	0.021
Percentage of sites with PD	<4 mm	FMD	74.5 %	90.6 %	0.036
	<4 mm	QS	68.9 %	86.2 %	0.014
	4–6 mm	FMD	19.6 %	8.7 %	0.010
	4–6 mm	QS	23.5 %	12.7 %	<0.001
	>6 mm	FMD	5.9 %	0.7 %	<0.001
	>6 mm	QS	7.6 %	1.1 %	<0.001
BOP (mean ± SD)		FMD	0.42 (±0.16)	0.12 (±0.043)	<0.001
		QS	0.47 (±0.21)	0.15 (±0.037)	<0.001

Inter-group comparisons were not significant at T1 and T2

*Intra-group comparisons through the McNemar and Wilcoxon tests, when appropriate

CHX may bring additional information to elucidate this issue. The effect of CHX in the reduction of VSCs was recently demonstrated [35]. However, there is a lack of knowledge about any possible chemical effects of isolate or combined CHX on CH_3SH [4].

Two methods to assess halitosis, the organoleptic method and the gas chromatography method, were used in the present study. Both methods have advantages and limitations. The most frequently used method, and still considered to be the gold standard for assessing halitosis, is the organoleptic method [3, 8, 9]. However, there are many disadvantages of this method of evaluation, such as the subjectivity of the test, the lack of VSC quantification, the saturating the examiner's sense of smell, and the lack of reproducibility [7, 11].

Currently, VSCs is used as the main marker for assessing bad breath. Moreover, it has been suggested that gas chromatography, due to its ability to identify and separately measure the gases qualitatively and quantitatively, is considered a more objective and sensitive method for analyzing VSCs [9, 10, 12, 27, 36]. Unfortunately, the OralChroma has a number of shortcomings (e.g., specificity, confounding factors, stability), which translate into moderate correlations between their readings and the organoleptic outcomes [7]. On the other hand, studies reported that the intensity of halitosis through organoleptic assessment is positively correlated with H_2S and CH_3SH [16, 37].

In the present study, evaluating halitosis by the organoleptic method showed significant reduction in scores at both T1 and T2 groups (FMD from 3.75 to 1.47 and QS from 3.89 to 2.10). Moreover, both treatment modalities showed significant reduction in CH_3SH after the intervention. This suggested that the elimination of bacterial deposits from the oral environment, disinfection, and inflammation reduction in both treatment strategies was effective in decreasing the perception of halitosis by the examiner.

Several studies have identified high levels of VSCs in subjects with periodontitis; however, few of them used gas chromatography as a method to evaluate these gases [36, 37]. Moreover, the VSCs showed a significant relationship with the periodontal status in clinical and epidemiological studies [24, 26, 30, 38], while others correlated the levels of these gases with various bacterial populations colonizing the subgingival environment and the back of the tongue [25, 26, 38, 39].

Findings from the present study showed that the gas most often associated with periodontitis, CH_3SH, showed very significant reductions after treatment in the FMD and QS groups. When CH_3SH was analyzed at the level ≥ 26 ppb, a significant reduction was also observed, which was not quantified at T2 due to the lack of identification of the minimum values of this gas (0.0 %). Regarding $H_2S \geq 112$ ppb, despite a reduction occurring from T1 to T2, this was considered not significant between the groups and times, yet previous studies have shown that this gas has not been correlated with a worse periodontal condition [5, 36].

Tongue coating is an important cause of bad breath odor in individuals with and without periodontal disease [13, 24, 29, 40, 41]. Mechanical cleaning of the tongue by brushing or using a scraper has proven to be effective in removing tongue coating [14]. In the present study, both treatment modalities (FMD or QS) significantly reduced the TCI between T1 and T2. The relationship between VSCs and tongue coating is well defined [36, 42–44]. However, the absence of this correlation has also been reported in previous studies [4, 29, 45]. Furthermore, some studies have occasionally reported high VSC levels in periodontally healthy individuals and attributed these findings to high levels of tongue coating [16, 44].

The main advantages of the present study can be considered its design, which differs from the others by comparing two different non-surgical periodontal treatment protocols and the use of two halimetry methods. However, results should be interpreted with caution. Selection biases related to specific inclusion and exclusion criteria, as well as difficulties in measuring and diagnosing halitosis, which involves multifactorial aspects, may also had occurred. Further, sample size and sample convenience in the present study may have some impacts on the external validity of the results. As such, further studies in different and larger populations may contribute to validating our findings.

Thus, the present study demonstrated that non-surgical periodontal therapy, regardless of the protocol, was effective in improving the periodontal clinical status of individuals with advanced chronic periodontitis and reducing halitosis.

Authors' contribution Dr. Fernando Costa has contributed to all stages of the research, including study design, data interpretation, and manuscript preparation. Dr. Juliana Silveira has contributed to halimetry examinations and periodontal treatment. Dr. Bernardo Carvalho has contributed to periodontal examination of eligible participants. Dr. Alcione Dutra has contributed to periodontal treatment of participants. Drs. Peterson Oliveira, José Cortelli, and Sheila Cortelli have contributed to initial screening and periodontal examination. Dr. Luís Cota has contributed to statistical analysis and data interpretation. All authors have contributed to the preparation and editing of the manuscript.

Compliance with ethical standards This study was approved by the Ethics Committee (#30378613.5.0000.5149) and registered at Clinicaltrials.gov (NTC02368678).

Conflict of interest The authors declare that they have no conflict of interest.

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Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964

Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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