The effect of professional tooth cleaning or non-surgical periodontal therapy on oral halitosis in patients with periodontal diseases. A systematic review

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Abstract
Objective: The aim of this systematic review was to give the best available evidence on the impact of professional tooth cleaning (PTC) and scaling and root planing (SRP) on oral halitosis in patients with periodontal diseases.

Material and methods: Three databases were screened for relevant studies. Only randomized controlled trials (RCTs) or controlled clinical trials (CCT) were included. The primary outcome in all included studies was volatile sulphur compounds (VSC) measured by Halimeter or OralChroma and organoleptic scores as secondary outcome. Only studies investigating healthy adults except for periodontitis or gingivitis were included. The considered intervention strategies were professional tooth cleaning and non-surgical periodontal treatment. For both strategies, additional oral hygiene instructions (OHI) were possible. Two independent reviewers performed the study selection and quality assessment.

Search results: After abstract and title screening and subsequent full-text reading of potential papers, a placebo-controlled RCT could not be found. However, eight studies or particular arms used PTC or SRP as sole interventions and were included in this review. All trials or study arms included showed a positive effect on VSC levels or organoleptic scores after intervention.

Conclusions: Based on best available evidence, PTC and SRP in combination with oral hygiene instructions reduced VSC values in patients with oral halitosis and/or periodontal diseases, independent of tongue cleaning and the use of mouth rinses.

KEYWORDS
bad breath, oral malodour, periodontal disease, periodontal treatment, volatile sulphur compound

1 | INTRODUCTION

Periodontal diseases are frequently accompanied by halitosis,1,3 and periodontitis is known to be the second most common cause for oral halitosis right after tongue coating.4,5 Bacteria associated with gingivitis and/or periodontitis, such as Porphyromonas gingivalis or Prevotella intermedia, are able to produce volatile sulphur compounds (VSCs).6 These VSCs including hydrogen sulphide (H2S) and methyl mercaptan (CH3SH) are the main components of malodour originating from the oral cavity.7 Both the bacteria causing halitosis and periodontal pathogens are mostly gram-negative and anaerobic.8

In periodontal patients with probing depths more than 4 mm, the concentrations of VSCs, particularly methyl mercaptan, were found to be higher compared to healthy controls.9 In an in vitro experiment, porcine epithelial tissues were treated with CH3SH,
resulting in severe cell damage or apoptosis.9 Even extremely low concentrations of VSCs proved to be toxic to the periodontal tissues,10 and it is presumed that VSCs can facilitate bacterial invasion into deeper tissues.3 Accordingly, not only do VSCs cause halitosis in terms of a lifestyle problem, but are also regarded as a periodontal pathogenic factor.

Scaling and root planing (SRP) and professional tooth cleaning (PTC) are essential elements of both an anti-infective therapy and a periodontal supportive therapy, not only in periodontitis patients but also in patients suffering from gingivitis.11,12 Taking into account that periodontitis is an important source of oral halitosis, we would anticipate that an additional benefit of both SRP and PTC would be a reduction in oral levels of VSCs and in oral halitosis.

However, systematic literature reviews exist only for the effect of tongue cleaning and mouth rinses on oral VSC concentrations and organoleptic scores13,14 and show beneficial effects for both measurements.

Therefore, the aim of this review was to elucidate the question whether anti-infective therapy independent from tongue cleaning and mouth rinsing already shows a beneficial effect on halitosis in patients with periodontal and gingival disease, and furthermore, whether or not anti-infective therapy is able to cure patients suffering from halitosis caused by periodontal disease. Specifically, this review aimed at the evaluation of the impact of PTC and SRP in addition to oral hygiene instructions (OHI) on oral halitosis in patients with periodontal diseases. Primary outcomes were the VSC concentrations measured by OralChroma (Abilit Corporation, Japan) or Halimeter (Interscan Co., Chatsworth, CA, USA), and secondary outcome the organoleptic scores.

2 | MATERIALS AND METHODS

2.1 | Search strategy

For this systematic review, three Internet databases were systematically screened to find all relevant studies up to January 2016. Regarding the focused question, our databases were as follows: PubMed-MEDLINE, Cochrane CENTRAL and Google Scholar. The search terms to evaluate the impact of preventive dentistry on halitosis are presented in Table 1.

2.2 | Study selection

Initially, two independent reviewers (H.C.D.D. and S.H.M.D.) read all selected papers considering title and abstract. Solely included were randomized clinical trials (RCTs) or controlled clinical trials (CCTs) published in English with an a priori design.

Letters, case reports or historical articles as well as unpublished data were excluded.

Inclusion criteria were as follows:

**Population:**
- Human subjects
- No systemic diseases affecting oral malodour except periodontitis or gingivitis
- Individuals aged at least 18 years

**Intervention in at least one study arm:**
- (a). Professional tooth cleaning; along with oral hygiene instructions.
- (b). Periodontal treatment: non-surgical periodontal treatment; along with oral hygiene instruction.
  - No additional conscious intervention like tongue cleaning and use of mouthwash during the evaluation period.

**Control:**
- No intervention like SRP or PTC in control group.

**Outcome:**
- Primary outcome: VSC concentrations (measured by sulphide monitor: Halimeter or gas chromatograph: OralChroma).
- Secondary outcome: organoleptic scores.

2.3 | Assessment of heterogeneity

All included studies showed homogeneity regarding the primary outcome (VSC levels), and some studies used additionally organoleptic scores as secondary outcome. The considered intervention strategies were non-surgical periodontal therapy and professional tooth cleaning combined with oral hygiene instruction.

The heterogeneity between the included studies regarding study design, subject selection and evaluation period is shown in Table 2.

2.4 | Quality assessment

Two independent reviewers (HCDD and MJN) examined the methodological quality of the included studies regarding characteristics of subjects, number of subjects, gender, mean age, evaluation period, intervention, outcome, authors’ conclusions and also the best available evidence in the interest of this review (Table 2).

As for quality criteria, we followed the Cochrane Handbook and the PRISMA statement.15
<table>
<thead>
<tr>
<th>No/Author/Year</th>
<th>Study design (particular arms/total arms)</th>
<th>Groups (selected for review)</th>
<th>No. of subjects baseline (end) Gender Age (mean/range)</th>
<th>Characteristics (inclusion, exclusion criteria, etc.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Soares et al, 2015¹ ²⁸</td>
<td>CCT Only test group without CHX and without tongue cleaning were included (1/4)</td>
<td>Generalized chronic periodontitis</td>
<td>? f: ? m: ? 47.74 ± 14.26 (38-66)</td>
<td>No systemic diseases Absence of dental decay No periodontal treatment in the previous 12 mo No antibiotics within the last 6 mo No history of radiation therapy for neck or head No current smoking</td>
</tr>
<tr>
<td>II Eid 2014³ ³⁶</td>
<td>Cross-sectional comparison (3/3)</td>
<td>Case group and test group with chronic periodontal disease Control group without periodontal diseases</td>
<td>? (60) f: 30 m: 30 31.35 ± 3.25 (25-35)</td>
<td>No data about smoking status No systemic disease No antibiotics within the last 6 wk</td>
</tr>
<tr>
<td>III Guentsch et al, 2013³⁷</td>
<td>CCT (2/2)</td>
<td>Test group with periodontal disease Control group periodontal healthy Analysed after first intervention (PTC)</td>
<td>42 (30) f: 18 m: 12 Test: 52 (25-72) Control: 26 (23-39)</td>
<td>No complain of halitosis No systemic diseases No pregnant or lactating females No antibiotics within the last 6 mo No smokers, no history of smoking No TC</td>
</tr>
<tr>
<td>IV Ehizele et al, 2013³⁸</td>
<td>CCT (2/2)</td>
<td>Test group with periodontal disease Control group without periodontal disease</td>
<td>? (400) ? 20-40</td>
<td>No systemic disease No smokers No orthodontic or prosthetic appliance</td>
</tr>
<tr>
<td>V Silveira et al, 2012²⁹</td>
<td>Clinical trial (without control group) (1/1)</td>
<td>Subjects with periodontal disease and generalized gingivitis</td>
<td>? (27) f: 14 m: 13 47.7 ± 7</td>
<td>No systemic disease No periodontal treatment in the last 6 mo No antibiotic and anti-inflammatory therapy in the last 6 and 3 mo No smokers At least 12 teeth present</td>
</tr>
<tr>
<td>VI Pham et al, 2011¹ ²⁷</td>
<td>CCT Only periodontal treatment arms are included of the RCT (2/4)</td>
<td>Test group 1 with periodontitis Test group 2 with gingivitis</td>
<td>229 (218) f: 113 m: 105 42.6 ± 8.5 (25-60)</td>
<td>Diagnosed with oral halitosis No systemic disease No periodontal treatment within the last 6 mo No pregnant or lactating females No TC instruction</td>
</tr>
<tr>
<td>VII Seemann et al, 2004⁴⁰</td>
<td>CCT (2/2)</td>
<td>Test group: patients from dental students course without periodontitis Control group: staff member of dental school without periodontitis</td>
<td>? (40) test group: 30 control group 10 f: ? m: ? 23-51</td>
<td>No systemic diseases No medication within 3 mo before and/or during the study No mucosal lesions No active periodontitis No complain of oral halitosis No regular TC No removable dentures At least 24 teeth</td>
</tr>
<tr>
<td>VIII Seemann et al, 2001¹¹</td>
<td>CCT (2/2)</td>
<td>Dental students</td>
<td>? (65) f: ? m: ? 22-31</td>
<td>No complain of halitosis No systemic disease No data about smoking status No regular TC</td>
</tr>
</tbody>
</table>

CCT, clinical controlled trial; RCT, randomized controlled trial; ?, unknown/not given; PTC, professional tooth cleaning; OHI, oral hygiene instruction; SRP, scaling and root planning; TC, tongue cleaning; HM, Halimeter; OC, OralChroma; ORG, organoleptic measurement; VAS, visual analogue scale; VSC, volatile sulphur compound.

¹Only study arms with SRP or PTC or suitable study phases were included.
²Post hoc analysis regarding tongue cleaning.
### Post hoc analysis regarding tongue cleaning. Scaling and root planning; TC, tongue cleaning; HM, Halimeter; OC, OralChroma; ORG, organoleptic measurement; VAS, visual analogue scale; VSC, Clinical controlled trial; RCT, randomized controlled trial; ?, unknown/not given; PTC, professional tooth cleaning; OHI, oral hygiene instruction; SRP, No data about smoking status.

**TABLE 2**

<table>
<thead>
<tr>
<th>Evaluation period</th>
<th>Intervention</th>
<th>Measurement</th>
<th>Selected authors conclusion</th>
<th>Best available evidence (sole impact of SRP, PTC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T0 baseline</td>
<td>Non-surgical periodontal treatment in quadrants</td>
<td>HM ORG</td>
<td>After intervention, there is a reduction in VSC level measured by Halimeter® and organoleptic scoring</td>
<td>For patients with generalized chronic periodontitis with moderate VSC levels at baseline. After non-surgical periodontal treatment, the VSC level decreases and it is still low after 90 d.</td>
</tr>
<tr>
<td>T1 day 30</td>
<td>Non-surgical periodontal treatment</td>
<td>HM</td>
<td>The periodontal group has the highest level of VSC with 230.8 ppb; the treated group showed 124.5 ppb, and the periodontal healthy group the VSC level is about 102.35 ppb.</td>
<td>Cross-sectional comparison For patients with periodontal diseases with higher VSC levels than healthy controls. After non-surgical periodontal treatment, patients have a lower VSC levels than patients with untreated periodontitis patients, but still higher than those without periodontitis.</td>
</tr>
<tr>
<td>T2 day 60</td>
<td>Test group: non-surgical periodontal treatment</td>
<td>HM</td>
<td>Statistically significant differences in the VSC of both groups were observed between baseline and T1. However in patients with periodontal diseases, a more complex treatment is necessary.</td>
<td>For patients with and without periodontal diseases with comparable VSC levels. 1. The reduction in VSC concentration after the PTC is higher in periodontitis patients than in healthy patients. 2. VSC levels increase again in patients having a periodontitis 14 d after intervention.</td>
</tr>
<tr>
<td>T3 day 90</td>
<td>Test group: no intervention</td>
<td>HM</td>
<td>At baseline VSC in no periodontal disease is 91.5 ppb while group with periodontal disease the VSC concentration is 228.5 ppb. Immediately after instituting the treatment, 364 of 400 subjects have a concentration less than 180 ppb.</td>
<td>For patients with periodontal diseases with double as high VSC levels than healthy control. After SRP, VSC levels are reduced in patients with periodontal problems, but it is still higher than in periodontal healthy patients.</td>
</tr>
<tr>
<td>T0 baseline</td>
<td>No randomization PTC</td>
<td>HM</td>
<td>Supragingival plaque control is effective in reduction of bad breath in patients with chronic periodontal disease.</td>
<td>For patients with periodontal diseases and with high VSC levels. 1. After PTC, the VSC concentration decreases, but it is still high. 2. After 180 d, the VSC level increases again.</td>
</tr>
<tr>
<td>T1 after intervention</td>
<td>No randomization PTC, OHI</td>
<td>HM</td>
<td>Periodontal therapy impacted an oral malodour reduction; however, the degrees of effect depending on periodontal status.</td>
<td>For patients with periodontal diseases with higher VSC levels than patients with gingivitis (CH3SH). SRP resulted more improvement of halitosis in patients with periodontitis than in patients with gingivitis especially regarding methyl mercaptan values.</td>
</tr>
<tr>
<td>T2 day 30</td>
<td>Test group: non-surgical periodontal treatment Control: tooth-brushing, OHI</td>
<td>HM</td>
<td>Patients having PTC and OHI show immediately after intervention and after 1 and 4 wk lower VSC concentrations compared to baseline. In patients without any intervention, there was no significant change regarding VSC level over the study period.</td>
<td>For patients without periodontal diseases. 1. Directly after PTC, the VSC concentration decreased compared with baseline. 2. After 1 and especially after 4 wk, the VSC levels increase again, but it is still lower than in patients without any treatment.</td>
</tr>
<tr>
<td>T2 plaque-free status (week 2)</td>
<td>No randomization PTC, OHI Control: no intervention</td>
<td>HM</td>
<td>In patients after PTC, the VSC values were significant lower 1 wk after PTC and at the end of the study compared to the untreated patients and baseline values.</td>
<td>For patients without periodontal diseases. 1. There are no changes regarding VSC levels after self-accomplished plaque-free status. 2. The VSC concentrations decrease after PTC. 3. VSC concentration increases again 4 wk after PTC, but is still lower than in patients.</td>
</tr>
</tbody>
</table>
2.5 | Data extraction and analysis

After abstract and full-text reading of the potentially relevant studies by two independent reviewers (HCDD and MJN) regarding the review’s objective, the studies that met the inclusion criteria were filtered out. The impact of the SRP and PTC on VSC levels and organoleptic scores was extracted.

A meta-analysis could not be performed with the included studies/study arms. Even if all studies reported VSC levels, they differed tremendously regarding included subjects and evaluation period. Therefore, a subgrouping focussing professional tooth cleaning or SRP was not possible, too.

2.6 | Grading the "body of evidence"

A GRADE evidence profile was performed as recommended by the GRADE working group regarding scaling and root planing and professional tooth cleaning.16 Two reviewers (HCDD and MJN) independently evaluated the quality of the evidence regarding study outcomes and the strength of the recommendation according to the following issues: risk of bias of the included studies/single study arms, precision and consistency among the studies, directness of the results and detection of potential publication bias. Any inhomogeneity between the reviewers was resolved after further discussion.

3 | RESULTS

3.1 | Search and selection results

In three databases (PubMed-MEDLINE, Cochrane CENTRAL and Google Scholar), a total of 339 unique titles and abstracts were found. After screening, the papers by title and abstract, 15 full-text articles remained, seven of which did not meet the inclusion criteria. In total, eight trials were included in this review (Fig. 1). After searching by hand, no additional papers were found. To collect more in-depth data, we also contacted various authors who had published the cited studies.

3.2 | Study design

Up to now, no classically designed RCT (parallel groups, control group without intervention) could be found related to the questions of this review. There are a number of clinical trials and several study arms that were used to answer the question by proving the best available evidence.

Five of the eight investigated studies were CCTs (#I, III, IV, VII and VIII). Study #II used a cross-sectional comparison, and study #V used a clinical trial without any control group. Only study VI was a RCT design; however, two of the four study arms were excluded because of additional intervention (tongue cleaning). In Study #I, also only one of the four study arms was included, and the other arms used additional interventions (eg, tongue cleaning or mouthwash) and therefore were excluded.

3.3 | Industry funding and side effects

None of the eight studies reported support by industrial funding or non-commercial grants. Moreover, no kind of side effects has been declared.

3.4 | Assessment of heterogeneity

Regarding characteristics of subjects, evaluation period, inclusion criteria and intervention, the eight selected studies utilized had strong heterogeneity (Table 2). All studies, except #II, measured the VSC concentrations levels before after intervention and included only healthy subjects except for their diagnosis of periodontitis or gingivitis who were aged at least 18 years of age.

3.5 | Quality assessment

The main problem comparing the included studies was the wide variety of subjects (both overall and within the single studies). Hence, there is a selection bias regarding the focused question in all of the eight studies (Table 3).

3.6 | Grading the "body of evidence"

The quality of evidence was rated by the GRADE system. Table 4 shows an overview of the quality of evidence as well as strength and direction of recommendation according to GRADE16,17 and also the level of certainty.18

We included single study arms in mainly control trials and CCTs, which might indicate a high risk of bias (Table 3). Publication bias however is unlikely.

Regarding VSC-levels, the direction of recommendation favours SRP over PTC in patients suffering periodontal disease. Organoleptic scores showed similar direction of recommendation.

3.7 | Characteristics of subjects

3.7.1 | Periodontal status

Studies #II, III and VI compared patients diagnosed with periodontal disease with subjects without periodontitis or gingivitis. In studies #I and V, all subjects suffered from periodontal or gingival diseases. Study #VI included two intervention groups, one with gingivitis and one with periodontitis. In study #VII, the control group consisted of staff members of dental clinic and study #VIII only investigated dental students. None of the study populations in trials #VII and #VIII showed any periodontal problems.
3.7.2 | Halitosis

Subjects in studies III and VIII had no complaints of obvious oral halitosis. In study VII, oral malodour could not be detected by organoleptic measurement at baseline.

Only one study included patients diagnosed with halitosis (IV). However, no explanation was provided whether the diagnosis was based on organoleptic or instrumentally scores, or whether the patients had diagnosed halitosis themselves. In the studies I, II, IV and V, the presence or absence of oral malodour was not considered as an inclusion criterion.

3.7.3 | Smoking status

Only one trial (VII) included smokers in the test group, but there were no smokers in the control group. Smoking was an exclusion criterion for trials I, II, IV and V. The other three studies (II, VI, VIII) were not explicit regarding patient selection and smoking status.

3.7.4 | Tongue cleaning

For the majority of the included trials, tongue cleaning performed by the participants was an exclusion criterion (III, VI, VII and VIII). The other studies (I, II and IV) did not report any information regarding tongue cleaning habits of the participants. Only trial V did a post hoc analysis if there was a difference in VSC levels as a result of tongue cleaning performed.

3.7.5 | Mouthwashes

None of the eight investigated studies state whether or not mouth rinses were used during or prior to SRP or PTC.

3.8 | Bias

The different types of bias are shown in Table 3. The evaluation of bias in the studies refers to the review’s objective and was based on Cochrane Handbook.15

3.9 | Outcome

3.9.1 | Comparison of VSC levels at baseline and after intervention

All investigated types of intervention showed a beneficial effect on halitosis (Table 5). Because of the different measurements (OralChroma,
<table>
<thead>
<tr>
<th>Study no., Author/Date</th>
<th>Selection bias</th>
<th>Performance bias</th>
<th>Possible Confounding factors</th>
<th>Attrition bias</th>
<th>Reporting bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Soares et al, 2015</td>
<td>No</td>
<td>No</td>
<td>• Removable dentures not reported</td>
<td>No data about dropouts reported</td>
<td>No</td>
</tr>
<tr>
<td>II Eid 2014</td>
<td>• Three groups: 1 intervention, 2 control groups • No randomization</td>
<td>Two control groups without intervention</td>
<td>• Smoking status not reported • TC not reported • Removable dentures not reported • No instruction before measurement</td>
<td>Unclear, no information provided</td>
<td>No data provided regarding baseline VSC in test group</td>
</tr>
<tr>
<td>III Guentsch et al, 2013</td>
<td>• Two intervention groups • No randomization</td>
<td>No</td>
<td>• Removable dentures not reported</td>
<td>No</td>
<td>Additional long term in periodontal group not comparable, data in healthy group missing</td>
</tr>
<tr>
<td>IV Ehizele et al, 2013</td>
<td>• Two intervention groups</td>
<td>Two different interventions</td>
<td>• TC not reported • Intake of antibiotics not reported</td>
<td>No data about dropouts reported</td>
<td>No subgrouping of test group into gingivitis and periodontitis</td>
</tr>
<tr>
<td>V Silveira et al, 2012</td>
<td>• Inhomogeneous diseased group • No control group • No randomization • Post hoc subgrouping by self-performance of TC</td>
<td>No</td>
<td>• Removable dentures not reported</td>
<td>No data about dropouts reported</td>
<td>No</td>
</tr>
<tr>
<td>VI Pham et al, 2011</td>
<td>• Two intervention groups</td>
<td>No</td>
<td>• Smoking status not reported • Removable dentures not reported</td>
<td>No</td>
<td>Per-protocol analysis reported, no information about intention-to-treat analysis</td>
</tr>
<tr>
<td>VII Seemann et al, 2004</td>
<td>• No randomization</td>
<td>No</td>
<td>• Control group of dental professionals • Smokers only in the intervention group</td>
<td>No data about dropouts reported</td>
<td>No</td>
</tr>
<tr>
<td>VIII Seemann et al, 2001</td>
<td>• No randomization</td>
<td>No</td>
<td>• Smoking status not reported • All participants dental students • Absence of including criteria</td>
<td>No data about dropouts reported</td>
<td>No</td>
</tr>
</tbody>
</table>
### TABLE 4  GRADE evidence profile for impact of SRP and PTC on halitosis parameters

<table>
<thead>
<tr>
<th>GRADE</th>
<th>SRP</th>
<th>PTC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study design</td>
<td>CCT</td>
<td>CCT</td>
</tr>
<tr>
<td>Studies No.</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Comparison No.</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Risk of bias</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Consistency</td>
<td>Inconsistent</td>
<td>Inconsistent</td>
</tr>
<tr>
<td>Directness</td>
<td>Generalized</td>
<td>Generalized</td>
</tr>
<tr>
<td>Precision</td>
<td>Rather imprecise</td>
<td>Rather imprecise</td>
</tr>
<tr>
<td>Publication bias</td>
<td>Undetected</td>
<td>Undetected</td>
</tr>
<tr>
<td>Level of certainty</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Magnitude of the effect</td>
<td>Strong recommendation for patients with untreated periodontitis and bad breath</td>
<td>Weak recommendation for patients with untreated periodontitis and bad breath</td>
</tr>
<tr>
<td>Direction of the recommendation</td>
<td>Strong recommendation for patients with untreated periodontitis and bad breath</td>
<td>Weak recommendation for patients with untreated periodontitis and bad breath</td>
</tr>
</tbody>
</table>

CCT, clinical controlled trial; PTC, professional tooth cleaning; SRP, scaling and root planing.

Halimeter, organoleptic measurement and visual analogue scale), an all-over comparison or meta-analysis could not be performed. Regarding Halimeter measurements (#I, III, IV, V, VII and VIII), the mean VSC concentration decreased after intervention (values at baseline (T0) between below 100 ppb and over 450 ppb: values after intervention (T1) between below 50 ppb up to 320 ppb).

In study #II, there was a lower VSC concentration in the group with periodontal treatment compared to the untreated group. The size of effect could not be determined because of missing pretreatment data. Authors reported a cross-sectional comparison.

In trial #VI, the VSC concentrations measured by OralChroma regarding methyl mercaptan decreased from over 450 ppb to below 100 ppb for patients with periodontitis. In patients suffering from gingivitis, the mean concentration was 150 ppb at baseline and about 100 ppb after intervention. Concerning hydrogen sulphide, the VSC levels decreased after intervention from over 500 ppb to below 200 ppb in patients with periodontitis and from over 400 ppb to below 350 ppb in patients with gingivitis.

In total, four trials (#I, III, V, VI) used additional organoleptic scores for halitosis detection, which were also positively influenced by intervention. The different organoleptic scores are shown in Table 5.

Only trial #V used a visual analogue scale (patient-based) to offer a subjective outcome after intervention (7 at baseline and 5 at T1).

### 3.9.2  Comparison of VSC levels at baseline

Except for trial VI, all studies used the Halimeter.

In trial #I, all subjects suffered from periodontitis and showed a mean baseline value of approximately 100 ppb VSCs. In trial #V, members of both test and control groups suffered from periodontitis or gingivitis with mean baseline values around 450 ppb and a maximum close to 2000 ppb.

For patients without any periodontal diseases (#VII and #VIII), the VSC levels for test and control groups at baseline were similar and accounted for 110 ppb (trial #VII) and 130 ppb (trial #VIII).

In three studies (#II, III, IV), the test group members suffered from periodontal disease while subjects of the control groups were periodontally healthy or had gingivitis. In all of these trials, Halimeter measurements were taken. The VSC baseline levels in periodontal groups in studies #II and IV were approximately 230 and 100 ppb in the accordant control groups. In study #III, there is almost no difference at baseline with approximately 70 ppb in subjects with periodontitis and the healthy control group.

Regarding the different VSC concentrations measured by OralChroma, mean hydrogen sulphide levels were above 500 ppb in the periodontal group and approximately 400 ppb in the gingivitis group. For methyl mercaptan, the mean concentration at baseline was approximately 450 ppb in patients suffering from periodontitis and approximately 150 ppb for patients with gingivitis.

### 4  DISCUSSION

Based on best available evidence, this review revealed the reduction in oral volatile sulphur compounds after periodontal therapy with SRP or PTC in patients with periodontitis or gingivitis. However, the extent of this reduction could not be assessed quantitatively due to the lack of RCTs and randomized control groups. Performing meta-analysis was not possible as VSC levels were scored by different types of equipment (OralChroma and Halimeter). Moreover, the various methods of intervention (SRP and PTC) and differences in selection of subjects, that is healthy patients vs patients suffering from gingivitis and periodontitis, made any comparison impossible.

Scaling and root planing in conjunction with supragingival plaque control (PTC) is the current method to treat patients suffering from chronic periodontitis.19,20

In general, patients with periodontitis showed more VSC reduction after SRP than healthy controls or those with gingivitis after PTC. The beneficial effect could be estimated, but the rated impact in comparison with other interventions like tongue cleaning13 or use of mouthwashes14 could not be determined. In gingivitis patients where PTC and mouthwashes or tongue cleaning are competitive approaches for halitosis treatment, the rated impact of each option would be important in the decision-making process, not only from a medical point of view but also under the aspect of a reasonable health economy.

However, of the eight included studies, none describes whether or not mouthwashes as an addition to SRP or PTC were used or recommended. This leaves room for discussion as the use of mouthwashes during the treatment of halitosis was stated to be beneficial.14 If mouth rinses were used, the magnitude of impact...
<table>
<thead>
<tr>
<th>Study/Year</th>
<th>Subjects characteristics in test and control group(s)</th>
<th>Intervention</th>
<th>Measurement</th>
<th>VSC level (mean)</th>
<th>Significant difference</th>
<th>Organoletic scores (mean)</th>
<th>Significant difference</th>
<th>Odour self-assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Soares et al, 2015</td>
<td>Periodontitis</td>
<td>SRP</td>
<td>HM</td>
<td>108</td>
<td>54</td>
<td>+</td>
<td>1.9</td>
<td>0.5</td>
</tr>
<tr>
<td>II Eid, 2014</td>
<td>Periodontitis</td>
<td>SRP</td>
<td>HM</td>
<td>/</td>
<td>124</td>
<td>n.s.</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>III Guentsch et al, 2013</td>
<td>Periodontitis</td>
<td>PTC + OHI</td>
<td>HM</td>
<td>77</td>
<td>47</td>
<td>+</td>
<td>n.a.</td>
<td>+ (Seemann: 0-3)</td>
</tr>
<tr>
<td>IV Ehizele et al, 2013</td>
<td>Periodontitis</td>
<td>SRP</td>
<td>HM</td>
<td>228</td>
<td>106</td>
<td>n.s.</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>V Silveira et al, 2012</td>
<td>Periodontitis and Gingivitis</td>
<td>PTC + OHI</td>
<td>HM</td>
<td>463</td>
<td>312</td>
<td>+</td>
<td>n.a.</td>
<td>n.s. (Rosenberg: 0-5)</td>
</tr>
<tr>
<td>VI Pham et al, 2011</td>
<td>Periodontitis</td>
<td>SRP</td>
<td>OC</td>
<td>H₂S: 535</td>
<td>186</td>
<td>+</td>
<td>2.86</td>
<td>1.45</td>
</tr>
<tr>
<td>VII Seemann et al, 2004</td>
<td>Periodontal healthy</td>
<td>PTC</td>
<td>HM</td>
<td>130^a</td>
<td>80^a</td>
<td>+</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>VIII Seemann et al, 2001</td>
<td>Periodontal healthy</td>
<td>PTC</td>
<td>HM</td>
<td>110^a</td>
<td>80^a</td>
<td>+</td>
<td>/</td>
<td>/</td>
</tr>
</tbody>
</table>

SRP, scaling and root planing; PTC, professional tooth cleaning; OHI, oral hygiene instruction; HM, Halimeter; OC, OralChroma; MM, methyl mercaptan; VAS, visual analogue scale; VSC, volatile sulphur compound.

^, contacted the author; all VSC samples were measured in ppb.
of either SRP/PTC or mouthwashes would be questionable as both treatments evidently lead to a reduction in halitosis parameters.

Incongruent data concerning the cut-off points for the definition of halitosis are described in the literature: studies correlating organoleptic scoring with Halimeter levels defined levels between 75 and 107 ppb as a threshold span,\textsuperscript{21} while the manufacturer of the device proposed 160 ppb (http://www.halimeter.com). OralChroma validity was not influenced by reducing the manufacturer's proposed detection limits, so the threshold levels were kept with 112 ppb for hydrogen sulphide and 26 ppb for methyl mercaptan.\textsuperscript{21} Not all studies showed a VSC reduction below the above-mentioned threshold values after intervention. Therefore, it remains questionable, whether or not the VSC reduction achieved is satisfying from the patient's perspective. For the individual patient, it still has to be considered if the PTC or SRP alone reached the treatment goal or if additional interventions (eg, tongue cleaning or mouthwashes) are needed to "cure" the halitosis.\textsuperscript{22,23}

4.1 | Sustainability

Five studies reported the long-term effect on VSC reduction (#I 90 days, #V 180 days, #IV 6 weeks, #VII 4 weeks and #VIII 10 weeks). After the first measurement (post-intervention) in four studies (#I, V, VII and VIII), the VSC levels increased steadily, but remained below the pretreatment values. Only in study #IV, the VSC levels decreased steadily, reaching values lower than 10 ppb without further intervention. Currently, there is no sufficient data available to define when a retreatment or additional interventions would be necessary.

4.2 | Study design

Up to now, no classically designed RCT (parallel groups, control group without intervention) regarding this review's objective could be found and therefore the overall "body of evidence" is low,\textsuperscript{24} even we pointed out the best available evidence.

From the classically designed RCTs,\textsuperscript{25-28} only one study arm could be included and two were excluded completely, as they examined the effect of SRP or PTC with additional use of antiseptics and/or tongue cleaning.

However, the included clinical trials and the single arms of studies performed could be interpreted as observational studies regarding the effect of PTC, SRP and/or oral hygiene instructions on halitosis. A recent methodological review proved the value of observational studies (OS).\textsuperscript{29} No significant differences between effects in trials with RCT design in comparison with observational studies were found.\textsuperscript{29} Conflicting data were not a result of the study design (RCT vs. OS) but could be attributed to others confounding factors.

The lack of classically designed RCTs should not lead to the conclusion that there is no evidence for an implication. The sum of the observational studies and study arms points at a conclusion in terms of best available evidence.

4.3 | Measurement/halitosis evaluation

4.3.1 | Instruments

Even if the organoleptic measurement is still the gold standard for halitosis evaluation,\textsuperscript{21,30,31} the use of Halimeter and/or OralChroma is more specific for this review's objective. Both devices measure the VSCs. The Halimeter gives an overall VSC value whereas the OralChroma distinguishes between the three main components of bad breath hydrogen sulphide, dimethyl sulphide and methyl mercaptan. Most of the included studies used the Halimeter\textsuperscript{78}; OralChroma was utilized in one study. As methyl mercaptan showed an association with periodontal diseases,\textsuperscript{9} the OralChroma measurements offer the most specific results for this review's topic, in particular because of the Halimeter's sensitivity, which is lower for methyl mercaptan than for hydrogen sulphide.\textsuperscript{32} The regularly demanded calibration of the OralChroma and Halimeter was not reported in any study. That may be an explanation for the tremendous differences between reported VSC values.

4.3.2 | Organoleptic scores

Regarding current literature, there are two main methods to assess halitosis. The comparison of both procedures however is almost impossible as both methods have highly different approaches. Rosenberg established a scoring system from 0 to 5 classifying the intensity of oral malodour.\textsuperscript{33,34} Reviewing Rosenberg's system critically the reproducibility of scoring bad breath by intensity might be questionable, as this method seems to be fairly dependent on the investigator. Later, Seemann developed a scoring system determining the distance in which oral malodour can be perceived.\textsuperscript{35} Seemann's procedure might lead to better reproducibility, as it seems to be less dependent on the investigator's subjective opinion.

4.3.3 | VSC values

Volatile sulphur compound values at baseline showed a wide range. Using Halimeter, a differentiation between periodontal diseases and healthy patients regarding VSC values was not possible. Baseline mean values in periodontally diseased groups ranged from 66 to 1976 ppb, while healthy controls showed 77 to 102 ppb. This may be attributed to the fact that the Halimeter measures an overall VSC value, being less sensitive for the periodontal-related methyl mercaptan. Using the OralChroma, periodontal patients showed three times higher mean baseline values of methyl mercaptan than patients with gingivitis.

Regarding changes after SRP in periodontal patients, methyl mercaptan levels were decreased (80% reduction), as was hydrogen sulphide (related to tongue coating, 65% reduction). Again it should be highlighted that the OralChroma measurements offer the most specific results for this review's topic.

4.4 | Limitations

The overall body of evidence is low for this review because of the lack of RCTs focusing our question. Therefore, we present the best
available evidence regarding the impact of PTC or SRP on oral halitosis.

Due to the heterogeneity of the included studies, no meta-analysis was performed. Most of these studies lack a classical control group (selection bias) and compare different kinds of intervention (performance bias).

Furthermore, there are known confounding factors such as smoking habits and regular tongue cleaning, which can influence and might alter instrumental measuring of sulphur compounds as well as organoleptic staging.

5 | CONCLUSION

Based on best available evidence, professional tooth cleaning or non-surgical periodontal therapy (scaling and root planning) in combination with oral hygiene instructions reduced oral halitosis represented by VSC values and organoleptic scores in patients with periodontal disease, independently of tongue cleaning and use of mouthwashes.

For patients with oral halitosis, a treatment plan should include a cause-related strategy. In cases of enhanced methyl mercaptan levels (indicating periodontal diseases), a treatment should start with professional tooth cleaning or scaling and root planning. If patients show increased hydrogen sulphide values that indicate tongue coating, this problem should be targeted first. Patients treated for periodontitis show reduced VSC levels and therefore might profit from the additional benefit of preventing or treating oral halitosis.

CLINICAL RELEVANCE

Scientific rationale for the study

Periodontal diseases are the second most common cause for oral halitosis. Periodontal pathogenic germs produce VSCs and are known to generate oral halitosis. Therefore, this review aimed to explore whether reducing such bacteria by professional tooth cleaning and/or scaling and root planning is able to cure oral halitosis in patients with periodontal disease.

Principle findings

Both mechanical plaque removal and scaling and root planning reduce oral halitosis. In patients suffering from periodontitis, the measured VSC concentrations are more elevated than in patients with gingivitis or periodontal healthy subjects. It is not possible to reduce halitosis parameters below the thresholds in all described cases.

Practical implications

Within the limitation of this review (body of evidence is low), PTC and SRP in healthy, gingivitis and periodontitis patients reduce VSC values as well as organoleptic scores. The beneficial effect of PTC and SRP is independent of the already proven tongue cleaning and use of mouthrines that should be need related combined in individual cases.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interests.

REFERENCES
