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J Bühler
M Amato
R Weiger
C Walter

A systematic review on the patient perception of periodontal treatment using air polishing devices

Authors' affiliations:
J Bühler, M Amato, R Weiger and C Walter, Department of Periodontology, Endodontology and Cariology, School of Dental Medicine, University of Basel, Basel, Switzerland
C Walter, Department of Oral Surgery, School of Dentistry, University of Birmingham, Birmingham, UK

Correspondence to:
C Walter
Department of Periodontology, Endodontology and Cariology
School of Dental Medicine
University of Basel
Hebelstrasse 3
CH-4056 Basel, Switzerland
Tel.: +41-61-2672628
Fax: +41-61-2672659
E-mail: clemens.walter@unibas.ch

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A systematic review on the patient perception of periodontal treatment using air polishing devices.

Abstract: *Objectives:* Air polishing devices are used as an alternative to traditional instrumentation of the root surface. The objective of the systematic review was to analyse patient perception, that is pain and discomfort during treatment with air polishing devices in periodontal therapy. *Methods:* The electronic databases MEDLINE, EMBASE and the Cochrane library were screened for studies published through 18th November 2013. Patient perception served as primary outcome. *Results:* Of the 1266 abstracts screened, nine studies reporting data on patient perception using a visual analogue scale or a patient interview were included in the analysis. Different air polishing powders consisting of sodium bicarbonate, glycine or erythritol were used. Reported discomfort of non-surgical periodontal therapy was consistently equal or lower when air polishing powders consisting of glycine or erythritol were applied compared with root surface instrumentation using hand instruments or ultrasonic devices. *Conclusion:* Air polishing with powders consisting of glycine seems to be associated with less discomfort during non-surgical periodontal therapy, that is supra- and subgingival air polishing.

Key words: air polishing; erythritol; glycine; non-surgical treatment; patient perception; sodium bicarbonate

Introduction

The goal of the initial subgingival scaling and root planing was the mechanical removal of biofilm and the formation of a root surface that is compatible with periodontal health (1–3). Despite evidence of cellular attachment between junctional epithelium and dental calculus, it is reasonably suggested to remove as much calculus as possible to reduce the adhesion of bacteria on its rough surface (1, 4, 5). Hand instruments, in particular Gracey curettes and ultrasonic scalers, are well established and scientifically proven for this treatment phase (6). After a systematic subgingival instrumentation and the subsequent establishment of 'closed periodontal pockets' (PD < 5 mm), a regular supportive periodontal treatment (SPT), including oral hygiene reinforcement and supra- and subgingival instrumentation, is required (5). When applied continuously, periodontal health is maintained over a period of several decades in compliant patients (7).

The treatment with Gracey curettes and ultrasonic scalers, however, may be associated with undesirable side effects, such as root substance removal (8), discomfort and pain during treatment (9). For example, patients often describe the conventional instrumentation of the root surface as being unpleasant (10). Patient perception, for example experienced discomfort during a therapy, is an important factor for acceptance of treatment, in

particular for the necessary long-term compliance of patients with chronic diseases, including periodontitis (11).

In the last decade, scientific interest has focused on developing alternative periodontal treatment approaches (12, 13). Air polishing devices for supragingival and, more recently, for subgingival application were clinically implemented (14).

The primary aim of this systematic review was to analyse patient perception, that is pain and discomfort during treatment, with air polishing devices in periodontal therapy, that is non-surgical supra- and subgingival air polishing.

Materials and methods

Protocols

The present systematic review considered the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) criteria (15, 16). The research questions were adapted using the Patient/Population, Intervention, Comparison, Outcomes (PICO) criteria (17).

Focused PICO question

What is the experience of pain and discomfort during non-surgical periodontal treatment with air polishing devices compared to hand instruments or ultrasonic scalers?

Review of the current literature

Information sources

The electronic databases MEDLINE, EMBASE and the Cochrane library were searched for studies published prior to 18th November 2013. Moreover, the references of publications examined for inclusion were thoroughly analysed to search for additional studies. The search terms are shown in Box 1.

Eligibility criteria

The selection of publications was limited to original controlled studies that provided data on patient perception after instrumentation using air polishing devices *in vivo*. The experience of pain and discomfort during non-surgical periodontal therapy had to be reported using a visual analogue scale (VAS) or a patient interview. Review articles, case reports and clinical notes and comments were excluded. Only studies in English or German language were considered. No time restrictions were applied.

Study selection

The combination of search terms resulted in a list of 1266 titles. The electronic bibliographic database searches were supplemented with hand searching of pertinent journals and bibliographies of identified publications. One thousand two hundred and fifty two titles from the electronic databases and 14 titles from the hand search were identified (Fig. 1). The reasons for exclusion are summarized in Appendix S1 (45–73). The study characteristics and the results related to the outcome parameters are summarized in Tables 1 and 2. The data on the effects of air polishing devices on oral tissues are presented separately.

Box 1
Search terms used for PubMed-MEDLINE, EMBASE and Cochrane Library

Search terms used for PubMed-MEDLINE, EMBASE and the Cochrane library. The search protocols in the different databases were validated and created as identical as possible.

Combinations of the search terms "Dental Prophylaxis/adverse effects" OR "Dental Prophylaxis/instrumentation" OR "Dental Prophylaxis/methods" OR "Dental Prophylaxis/standards" OR "Dental Polishing" AND ((air AND polish*[OR subging*)) were applied.

The following search terms were used:

Medline:

"Dental Enamel" [Mesh] OR "Dental Prophylaxis/adverse effects"[Mesh] OR "Dental Prophylaxis/instrumentation" [Mesh] OR "Dental Prophylaxis/methods" [Mesh] OR "Dental Prophylaxis/standards" [Mesh] OR "Dental Polishing" [Mesh]) AND ((air [tiab] AND polish*[tiab]) OR subging* [tiab].

Embase:

'enamel'/exp AND 'preventive dentistry'/exp AND 'mouth hygiene'/exp AND 'dental equipment'/exp AND 'procedures'/exp AND 'gold standards'/exp AND 'tooth brushing'/exp AND 'dental surgery'/exp AND 'periodontics'/exp.

Cochrane:

[Dental Cementum] explode all trees OR [Dentin] explode all trees AND [Periodontics] explode all trees OR [Periodontal Debridement] explode all trees OR [Dental Prophylaxis] explode all trees AND [Air Abrasion, Dental] explode all trees OR [Subgingival Curettage] explode all trees OR [Dental Polishing] explode all trees.

Data collection process

Data items

The following data were collected in data extraction files: (P) number, age and gender of patients, (I) setting (SPT, prophylaxis treatment, application and direction of the powder spray, air polishing device, duration of follow-up), (C) air polishing powder, control treatments and measurements, (O) patient perception.

Risk of Bias in individual studies

The risk of bias in the individual studies was evaluated using the Cochrane Collaboration's Tool for assessing risk of bias (15) and the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) statement (16) (Appendix S2). Some of the items for assessing the risk of bias were modified to meet the requirements of this review. Considering the adequacy in the respective studies, the studies were graded and the percentage of positively graded items was calculated (15, 17) (Appendix S3).

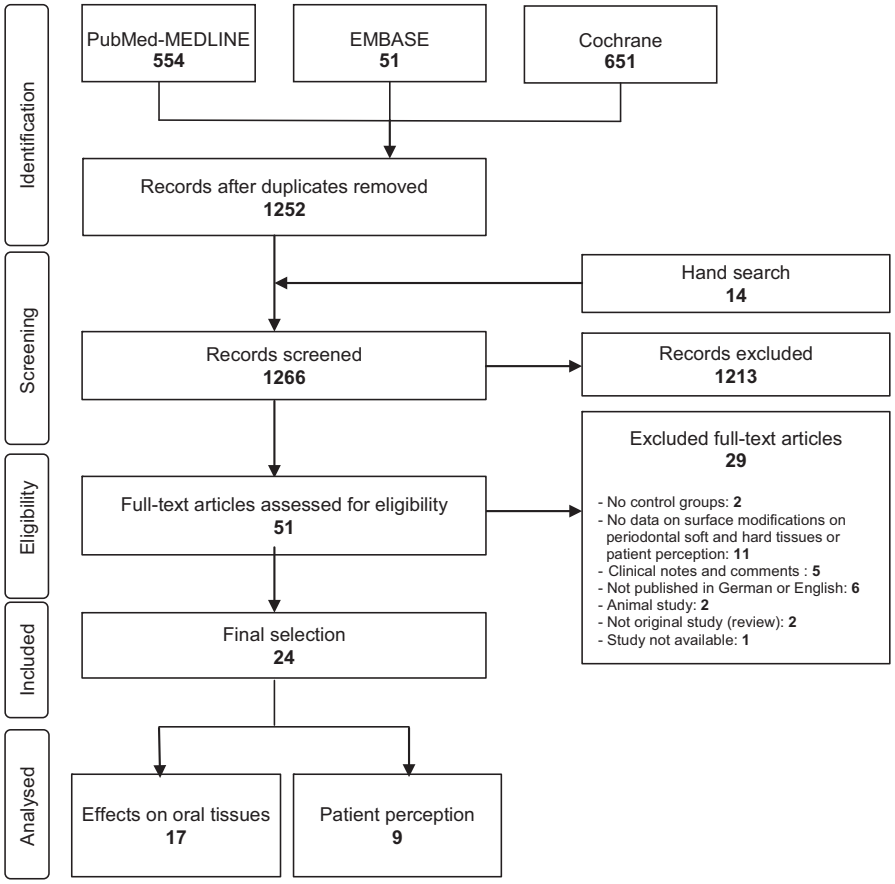

Fig. 1. Selection process of the studies included

Synthesis of results

A great heterogeneity in setting parameters, spraying protocols and data analysis exists among the studies included in the review. Therefore, a meta-analysis was not appropriate and was not performed. However, to provide a limited synthesis of the evidence of the included data, a vote counting method was applied (http://handbook.cochrane.org/chapter_9/9_4_11_use_of_vote_counting_for_meta_analysis.htm).

Results

Summary measures

Patient perceptions were measured with VAS in five publications (12, 18–21), and all nine publications reported the individual statements of the patients applying interviews.

Study selection

The located titles and abstracts were screened for compliance with the inclusion criteria for both parts of the review by the authors (J.B. and M.A.). A third reviewer (C.W.) resolved any disagreements and made the final decision. Fifty-six publications were selected for eligibility. The agreement between the reviewers was calculated using a Bayesian approach indicating a kappa value 0.795 and a credible interval (corresponding to a conventional confidence interval) $0.773 < ICC < 0.816$. This value represented a substantially strong agreement. Full-text analysis of the 51 publications, selected by at least one reviewer, led to exclusion of further 29 publications. The reasons for exclusion are summarized in Table 1.

Of the remaining 24 publications, seven studies from the electronic search and two additional publications satisfied the inclusion criteria for this review (Fig 1). The studies were published in the period from 1985 to 2013.

The remaining 17 studies were analysed in a separate manuscript, that is the effects of air polishing devices on oral tissues.

Summary of characteristics (PICO – Population, Intervention/Comparison, Outcomes)

Population – number and characteristics of subjects and teeth

The study characteristics and the results related to the outcome are summarized in Tables 1 and 2.

The studies provided a mean age of the included patients, which ranged from 46.4 ± 10 years (19) to 63.9 ± 8.3 years

Table 1. **Characteristics of included studies**

Author and Citation Number	Number of patients Mean Age Gender	Setting Application, Direction of the powder spray	Device	Duration	Powder Grain size Control treatment	Measurements
Hägi *et al.* (21)	40 Test group: 55.2 ± 7.79 40% F, 65% M Control Group: 53.7 ± 10.09 40% F, 65% M	SPT[§] Subgingival Horizontal	Perio Flow handpiece for Air Flow Master[†]	3 months	Erythritol powder n.r. Curettes	VAS[¶¶], Interview
Flemmig *et al.* (20)	30 63.9 ± 8.3 years 15 F, 15 M	SPT[§] Subgingival Horizontal, Supragingival Coronal to apical	Perio Flow handpiece for Air Flow Master[†]	3 months	Glycine D_{v50} (19 μm)*** Curettes	VAS[‡‡], Interview
Wennström *et al.* (18)	20 60 years 14 F, 6 M	SPT[§] Subgingival Horizontal	Perio Flow handpiece for Air Flow Master[†], Piezon Master 400, PerioSlim tip[†]	2 months	Glycine ~25 μm[†††] Ultrasonic device	VAS[††], Interview
Moëne *et al.* (12)	50 54.9 ± 10.9 years 24 F, 26 M	SPT[§] Subgingival Horizontal	Perio Flow handpiece for Air Flow Master[†]	7 days	Glycine ~20 μm Curettes	VAS[††], Interview
Flemmig *et al.* (22)	60 n.r. n.r.	EPT**, SPT[§] Supragingival Coronal to apical	Air Flow S1[†]	Analysis directly after treatment	Glycine ~25 μm***	Interview
Petersilka *et al.* (23)	23 47.31 ± 11.6 years 10 F, 13 M	SPT[§] Supragingival Coronal to apical	Air Flow S1[†]	9 months	Glycine D_{v90} (63 μm)[‡‡‡] Curettes	Interview
Petersilka *et al.* (19)	27 46.4 ± 10 years 11 F, 16 M	SPT[§] Supragingival Coronal to apical	Air Flow S1[†]	3 months	Glycine D_{v90} (63 μm)[‡‡‡] Curettes	VAS[§§], Interview
Kontturi-Närhi *et al.* (24)	20 20–50 years n.r.	PT[¶] Supragingival n.r.	Air Flow[†]	Analysis directly after treatment	Sodium bicarbonate n.r.	Interview
Mishkin *et al.* (25)	21 n.r. 3 F, 18 M	PT[¶] Supragingival Coronal to apical	ProphyJet[‡]	21 days	Sodium bicarbonate n.r.	Interview

F: Females; M: Males; n.r.: not reported.
* $P < 0.05$.
[†]EMS, Nyon, CH
[‡]Dentsply, York, USA.
[§]SPT: Supportive periodontal treatment, subgingival application of the air polishing powder.
[¶]PT: Prophylaxis treatment, supragingival application of the air polishing powder.
**EPT: Experimental periodontal treatment, subgingival application of the air polishing powder with no previous instrumentation of the root surface.
[††]VAS: Visual analogue scale (100 mm) scoring 'degree of treatment discomfort'. Range: 'none' = value 0, 'unbearable' = value 100.
[‡‡]VAS: Visual analogue scale. Range: 'very comfortable' = value 0, 'excruciating pain' = value 10.
[§§]VAS: 10-point linear visual analogue scale. Range: 'good experience' = value 10, 'bad experience' = value 1.
[¶¶]VAS: visual analogue scale. Range: 'most comfortable perception' = value 0, 'most uncomfortable perception' = value 10.
***D_{v50} (19 μm): 50% of powder particles >19 μm.
[†††]~25 μm: Not provided in the publication. Values according to manufacturer's homepage.
[‡‡‡]D_{v90} (63 μm): 90% of powder particles >63 μm. Not provided in the publication. Values according to manufacturer's homepage.

Table 2. **Outcome of included studies**

Author and Citation Number	Patient perception	Rating of Discomfort (vote counting method)					
		Erythritol	Glycine	Sodium bicarbonate	Curettes	Ultrasonic scaler	Rubber cup/paste
Hägi *et al.* (21)	Discomfort: Curettes > erythritol* *Adverse events:* None	0	n.a.	n.a.	+	n.a.	n.a.
Flemmig *et al.* (20)	Discomfort: Curettes ('high') ≈ glycine ('high')† Adverse events: Glycine: 8 in 7 patients Curettes: 9 in 5 patients	n.a.	0	n.a.	0	n.a.	n.a.
Wennström *et al.* (18)	Discomfort: Ultrasonic (15) > glycine (7.5)* Adverse events: None	n.a.	0	n.a.	n.a.	+	n.a.
Moëne *et al.* (12)	Discomfort: Curettes (2.2) > glycine (0.9)* Adverse events: None	n.a.	0	n.a.	+	n.a.	n.a.
Flemmig *et al.* (22)	Adverse events: None	n.a.	0	n.a.	n.a.	n.a.	n.a.
Petersilka *et al.* (23)	Adverse events: 1 Patient with slight but painless bleeding at one site, 1 Patient with prickling sensation of the skin	n.a.	+	n.a.	0	n.a.	n.a.
Petersilka *et al.* (19)	Discomfort: curettes > glycine*,† Adverse events: None	n.a.	0	n.a.	+	n.a.	n.a.
Kontturi-Närhi *et al.* (24)	Adverse events: 75% of patients with subjective symptoms during sodium bicarbonate treatment; 45% immediately after treatment	n.a.	n.a.	+	n.a.	n.a.	n.a.
Mishkin *et al.* (25)	Adverse events: 3 patients reported a peeling off of the inner aspects of the lower lip	n.a.	n.a.	+	n.a.	n.a.	0
Sum		0	1	2	3	1	0
Number of studies analysing this treatment		1	6	2	5	1	1
Score†		0	0.17	1	0.6	1	0

*$P < 0.05$.

†No numbers provided/data provided as figures.

‡Score: For this analysis, two treatments were compared in each study. The treatment causing statistically significant more discomfort received '+' in increasing numbers for the comparison of the treatments in the respective study. The score was calculated by dividing the number of '+' by the number of studies analysing this treatment. A higher score provides a proximate for the increased discomfort perception by the patient.

n.a., not applicable.

(20). One study did not provide a mean age, but disclosed an age range of 20 to 50 years (24). Two studies gave no information about the age of included patients (22, 25). None of the included studies mentioned the ethnicity of study patients. The number of patients ranged from 20 (24) to 60 patients (22) in the publications. The overall number of patients was 291 (Tables 1 and 2). Seven studies mentioned the sex of patients (12, 18–21, 23, 25). Inclusion criteria were described at the patient level and were occasionally specified with respect to the analysed teeth. In all included studies, patients were stated systemically healthy. Whereas one study did not provide any information about medication of the included patients (24), all other studies defined specific medication (12, 18–23, 25) as exclusion criterion. Tobacco use was not a reason for exclusion in six studies (12, 18, 19, 21–23), two studies did not report smoking habits (24, 25), and one study excluded patients who smoked more than five cigarettes a day (20). The included patients suffered from either severe periodontitis (22), moderate-to-advanced chronic periodontitis (18–21, 23) or not further defined 'periodontal disease' (12). Two publications did not report the status of the included patients (24, 25). The gingiva of the patients was either stated as healthy (18, 24, 25) or a slight gingivitis was diagnosed (24, 25). Six publications gave no information about the gingival conditions of the patients (12, 19–23). Patients were undergoing SPT (12, 18–23), prophylaxis treatment (24, 25) or an 'experimental periodontal treatment' followed by extraction of the instrumented teeth (22).

Intervention – methods and measurements

Methods

Air polishing devices and powders

Devices

AIR-flow devices (EMS SA, Nyon, Switzerland) (12, 18–24) and Prophyjet (Cavitron Dentsply International, York PA, USA) (25) were used.

Powders

Either sodium bicarbonate (24, 25), glycine (12, 18–20, 22, 23) or erythritol (21) was used as air polishing powders in the included studies, whereas the grain sizes of sodium bicarbonate powders used were not mentioned (24) (25). The grain sizes of glycine powders ranged from ~19 μm (20) to <63 μm (23) (Table 1). The study testing the erythritol powder simply stated a grain size comparable to that of glycine (21).

Treatment parameters

Exposure times varied from 5 s (22) to 10 s (18) per tooth (22) or site (18). One publication measured treatment time per dentition between 5 and 10 min (24). The angulation of the spraying nozzle was defined as an 'acute angle (20, 22), 60°–90° (25) or as parallel to the long axis of the root (21, 23). The remaining publications did not mention the nozzle angulation (12, 18–20, 24). A spraying distance was provided in one publication (4–5 mm) (25). Four of the included studies applied glycine powder (12, 18, 20) or erythritol powder (21) subgingivally with a special application nozzle that directed the powder jet horizontally to the root surface. Six studies applied the powder supragingivally; four of them applied glycine powder (19, 20, 22, 23), and two applied sodium bicarbonate (24, 25). Most of the studies sprayed the powder in a coronal to apical direction to the tooth surfaces, whereas one study did not report the spraying direction (24).

Measurements

Patient perceptions were analysed using different VAS (12, 18–21) (Table 1). The individual statements of the patients were assessed after treatment using interviews by all studies (12, 18–25).

Outcomes

Patient perception

Visual analogue scales:

While in four studies, the glycine or erythritol powder was applied subgingivally (12, 18, 20, 21), in one study glycine powder was used supragingivally (19). In one study, subgingival treatment with glycine powder was significantly more comfortable and less painful (VAS 0.9) compared with scaling and root planing with curettes (VAS 2.2, $P < 0.001$) (12). Similar results were shown for the subgingival application of erythritol powder ($P = 0.0006$) in another study (21). No significant differences between the subgingival treatment with glycine powder or with curettes were found in one publication (20). Subgingival glycine powder air polishing was also compared to an ultrasonic device, and patients reported significantly less discomfort scores for treatment with glycine powder (VAS 7.5 vs. 15.0, $P < 0.05$) (18).

In one study, patient perception during supragingival application of glycine powder indicated significantly less discomfort ($P < 0.05$) compared with treatment with hand instruments, without providing numerical data (19).

Interviews

One publication stated that 75% of the patients experienced subjective symptoms during supragingival treatment with sodium bicarbonate powder, and 45% experienced symptoms immediately after treatment (24). Another publication indicated that three patients complained about a peeling off of the inner aspects of the lower lip after supragingival polishing with sodium bicarbonate powder (25). A case of slight but painless bleeding at one site, and a patient who experienced a transient prickling sensation on the skin of his cheeks after supragingival glycine powder application were reported in one study (23) . Eight adverse events in seven patients were described after subgingival treatment with glycine powder. Curettes were

applied in the control group and resulted in nine adverse events in five patients (20). The most frequent adverse events were 'gastrointestinal system disorders' (in five patients of the test group and four of the control group) and 'resistance mechanism disorders' (in one test and three control patients). All other adverse events were not further described but were considered not to be related to the treatment. Furthermore, the authors stated that no serious adverse events occurred.

Five publications found no adverse effects, with supragingival (19, 22) or subgingival application of glycine (12, 18) or erythritol (21) powder.

Risk of bias

At least 52% of items relevant for quality assessment were considered in all included studies, except in one study (Appendix S3). No study fulfilled all items for control of bias.

The protocol of seven studies was ethically approved. Eligibility criteria for included patients and the applied methods in detail were described in all included studies. Examiner calibration and validation of reproducibility were not always reported. Variability of results was presented by means with standard deviations and/or range of individual values in all but one study. Six studies reported data on all outcome variables in terms of number of participants and tooth sites, control treatment and the presence or absence of periodontal diseases.

Discussion

The aim of this systematic review on air polishing devices was to analyse the patient perception of air polishing devices in different aspects of non-surgical periodontal treatment. The important patient-oriented outcome – patient perception – was defined. Finally, nine publications met the inclusion criteria.

Patient perception was analysed by all nine publications. However, a validated instrument for assessment in terms of a VAS was applied in five studies (12, 18–21). The assessments from VAS showed that glycine powder air polishing is perceived as significantly less uncomfortable (12, 18, 19, 21) or equally comfortable (20) (Score: 0.17, Table 2) to treatment with ultrasonic devices (Score: 1) or curettes (Score: 0.6). Nine studies reported data from an interview with the patient and indicated no severe adverse events after spraying with glycine powder (12, 18–25). Interestingly, three studies reported data on PPD changes and indicated similar results for glycine powder polishing compared with a treatment with ultrasonic devices (18) or curettes (20) after 2 (18) and 3 months, respectively (20). Air polishing with an erythritol powder resulted in a significant reduction in PPD values after 3 months. This was comparable with the PPD-reduction after treatment with curettes in the control group (21).

The initial periodontal treatment is performed after a thorough clinical and radiographic examination, diagnosis, treatment planning and case presentation. This phase consists of oral hygiene instructions, help with tobacco use cessation, splinting of teeth, endodontic treatment, extraction of teeth irrational to treat and the removal of plaque/biofilm and calculus by non-surgical scaling and root planing (5). Today, a few instruments complement proven techniques are available for the removal of subgingival biofilm and/or scaling and root planing of the diseased periodontia. Focus of the initial instrumentation is not only the removal of biofilm, but also the formation of a root surface, which is compatible with periodontal health. While aim, amount and time of the instrumentation of the root surface are still under scientific debate (2), a smooth, hard and decontaminated root surface is requested by several authors (1, 5, 33). Indicated therefore are hand instruments including Gracey curettes and ultrasonic scalers (6). Such an absolutely necessary treatment, however, may be associated with a few undesirable side effects (34), leading to the ongoing search for the improvement of non-surgical periodontal treatment (13). Treating the root surface for many years contributes to a significant removal of tooth substance (8, 33). Occasionally, teeth may develop a high risk of fracture (35). Following initial subgingival instrumentation, most sub- and supragingival calculus should have been removed. For many teeth, the removal of biofilm therefore becomes the sole focus of attention in subsequent SPT. Conventional instrumentation using curettes and ultrasonic devices may cause pain (10, 36). Consistently, an increased discomfort was described by the patients treated in the control group of the included studies (12, 18–21). The association between patient perception and compliance to supportive periodontal treatment (SPT) appears likely. However, the publications included do not report on this relationship. Data from the treatment of chronic diseases, including HIV/Aids, cardiovascular diseases and diabetes, indicate that the adherence to the suggested therapy depends on compliance and patient perception (37). So far, the assumption appears reasonable and is supported by clinical experience, that discomfort during and following treatment diminishes patient's compliance, in particular in the long term.

Accordingly, SPT is to favour minimally invasive and patient-friendly procedures of biofilm management. The patient perception was the primary outcome parameter in this review. The data from four studies are consistent and report a low experience of discomfort and a minor potential of harm for air polishing devices using glycine powder. However, the authors of three included studies (12, 19, 23) declare that SPT with glycine air polishing devices alone is not enough for patients with high calculus deposits, due to the low abrasive capacities of the powder. It is stated that calculus still has to be removed using conventional therapy with ultrasonic and/or hand instruments. Another *ex vivo* study supports this statement by mentioning that it was even not possible to remove calculus from the root surface with a sodium bicarbonate air powder abrasive (38).

When active therapy was successful, the periodontal patient is included in a SPT programme with 3- to 4-month intervals (5, 39). This combination is described as the basis and the 'gold standard' of periodontal treatment. When applied consistently, periodontal health can be maintained in long term (40,

41), disclosing in the latter study a time frame of up to 30 years of SPT. In this review, three studies reported data on PPD changes (18, 20, 21). Results look promising for a follow-up of 2 (18) to 3 months (20, 21). They need to be considered as short-term clinical studies and therefore may not represent long-term efficacy in SPT. Well-performed clinical studies addressing long-term efficacy with respect to patient perception supplemented with PPD changes are required.

Periodontal treatment aims in the establishment of 'closed periodontal pockets' (PD <5 mm) (42). Sites with residual PPD of ≥6 mm require additional therapy to prevent further attachment loss or even tooth loss during supportive periodontal therapy (39). One study included in this review demonstrated the removal of stained biofilm using glycine powder air polishing up to a so-called anatomic probing depth (APD) ≤3 mm (22). This may represent a probing depth of ~5 mm. The air polishing in this study was conducted supragingivally, with the spraying nozzle pointed in the sulcus in a coronal to apical direction. In deeper pockets, the efficacy of air polishing is not sufficiently documented.

Limitations

When the data are analysed, the following issues need to be considered:

1 Although there may be more data presenting information about the outcome variables in this review, the search was restricted to the literature available in the electronic databases Pubmed, Embase and the Cochrane library in the English and German language.

2 All the included studies were published during 1985 and 2013. As treatment concepts in dentistry as well as dental materials change in the course of time, to some degree the work included in this review describes the development of air polishing devices over the years. This becomes apparent when considering the content of the powders as well as the areas for clinical use of the air polishing devices, which changed from supra- to subgingival in recent years.

3 One should keep in mind that the included publications used different air polishing devices. Different devices feature different technical parameters, such as variable powder emission rates and air pressure. Therefore, patient perception and the clinical treatment outcomes achieved need to be interpreted with care and are not comparable by implication (26).

4 Moreover, the applied treatment parameters such as the direction and application of the air-powder spray varied within a great range among the analysed publications. In addition, the air polishing devices were applied using powders consisting of sodium bicarbonate (22), glycine (12, 18–20, 22, 23) or erythritol (21). Several publications demonstrated that different powder grain sizes and also different air polishing powders and applications lead to different effects on the root surface (13, 26–29). These discrepancies may also affect the clinical outcomes of the included publications. To what extent the percentage rate of a mean different grain size of powders consisting of glycine (~19 vs. <63 μm) (Table 2) affects patient perceptions during treatment has not been analysed within a comparative study.

5 In some included studies, the powder was delivered supragingivally with the powder jet directed to the sulcus to reach subgingival areas of the root surface (19, 22–25). Four of the included studies applied glycine powder subgingivally with an application nozzle inserted directly into the periodontal pocket that directed the powder jet horizontally to the root surface (12, 18, 20, 21). These different delivery methods may influence patient perception.

6 So far, none of the studies with the subgingival nozzle-type instruments have a negative control group assessing the perception of an instrumentation of the pocket with the nozzle alone, without using powder or water, respectively.

7 There is some evidence that air emphysema can occur with all types of air polishers (30–32). Nonetheless, neither any of the included studies in this review mentioned any serious adverse events, nor an air emphysema occurred, even treating deep pockets with ≤9 mm PPD by an air polishing device (12).

8 None of the included studies in this review were funded independently, and most were established in close cooperation with the manufacturer of the assessed products (12, 18, 20–23, 25) – this might raise the risk of bias.

Conclusion

The Level of evidence and the strength of recommendation of the included studies were evaluated according to the SORT-Grading Taxonomy (43, 44). For patient perception, the A level for the strength of recommendation and level 1 for quality of evidence could be applied. The level of evidence regarding patient perception of periodontal treatment using air polishing devices can therefore be considered as high, that is according to the definition: 'we are very confident that the true effect lies close to that of the estimate of the effect' (http://www.jclinepi.com/article/S0895-4356(10)00332-X/fulltext). Consistent, good-quality patient-oriented evidence from this review suggests minor discomfort experienced by the patients treated with air polishing powders, in particular with glycine powder.

Directions for further research

The consideration of the following parameters is suggested for future research:

Application of:

1 Air polishing powders containing novel ingredients or grain sizes. Information about clinically relevant constituents and grain sizes should be provided by the manufacturer.

2 Appropriately defined eligibility criteria (e.g. systemic diseases, medication, smoking habits, periodontal disease category, etc.) for included patients.

3 Continuing assessment of patient perception with validated methods (i.e. VAS).

Clinical relevance

Scientific rationale for the study

Air polishing devices were applied supra- and subgingivally and are considered as an alternative approach in supportive periodontal treatment (SPT).

Principal findings

Nine publications were analysed in a systematic review with respect to patient perception. There is sufficient evidence for less discomfort in patients treated with air polishing devices, in particular with glycine powders.

Practical implications

Patients treated with air polishing devices consisting of glycine powder report consistently less discomfort. Further evidence with respect to other powders and clinical applications and parameters in the long term is required.

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Conflict of interest and sources for funding

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References

1 Badersten A, Nilveus R, Egelberg J. Effect of nonsurgical periodontal therapy. I. Moderately advanced periodontitis. *J Clin Periodontol* 1981; **8**: 57–72.
2 Van der Weijden GA, Timmerman MF. A systematic review on the clinical efficacy of subgingival debridement in the treatment of chronic periodontitis. *J Clin Periodontol* 2002; **29**: 55–71; discussion 90-1.
3 Garrett S, Johnson L, Drisko CH *et al.* Two multi-center studies evaluating locally delivered doxycycline hyclate, placebo control, oral hygiene, and scaling and root planing in the treatment of periodontitis. *J Periodontol* 1999; **70**: 490–503.
4 Listgarten MA, Ellegaard B. Electron microscopic evidence of a cellular attachment between junctional epithelium and dental calculus. *J Periodontal Res* 1973; **8**: 143–150.
5 Walter C, Buset S, Thillainathan L, Weiger R, Zitzmann NU. Evaluation of periodontal therapy in undergraduate courses of the University of Basle. *Schweiz Monatsschr Zahnmed* 2013; **123**: 861–869.
6 Walmsley AD, Lea SC, Landini G, Moses AJ. Advances in power driven pocket/root instrumentation. *J Clin Periodontol* 2008; **35**: 22–28.
7 Axelsson P, Nyström B, Lindhe J. The long-term effect of a plaque control program on tooth mortality, caries and periodontal disease in adults. Results after 30 years of maintenance. *J Clin Periodontol* 2004; **31**: 749–757.
8 Ritz L, Hefti AF, Rateitschak KH. An *in vitro* investigation on the loss of root substance in scaling with various instruments. *J Clin Periodontol* 1991; **18**: 643–647.
9 Canakci CF, Canakci V. Pain experienced by patients undergoing different periodontal therapies. *J Am Dent Assoc* 2007; **138**: 1563–1573.
10 Braun A, Jepsen S, Deimling D, Ratka-Krüger P. Subjective intensity of pain during supportive periodontal treatment using a sonic scaler or an Er:YAG laser. *J Clin Periodontol* 2010; **37**: 340–345.
11 Muhney KA, Dechow PC. Patients' perception of pain during ultrasonic debridement: a comparison between piezoelectric and magnetostrictive scalers. *J Dent Hyg* 2010; **84**: 185–189.
12 Moëne R, Décaillet F, Andersen E, Mombelli A. Subgingival plaque removal using a new air-polishing device. *J Periodontol* 2010; **81**: 79–88.
13 Petersilka GJ, Bell M, Häberlein I, Mehl A, Hickel R, Flemmig TF. *In vitro* evaluation of novel low abrasive air polishing powders. *J Clin Periodontol* 2003; **30**: 9–13.
14 Sculean A, Bastendorf KD, Becker C *et al.* Paradigm shift in mechanical biofilm management? *Quintessence Int* 2013; **44**: 475–477.
15 Graziani F, Figuero E, Herrera D. Systematic review of quality of reporting, outcome measurements and methods to study efficacy of preventive and therapeutic approaches to peri-implant diseases. *J Clin Periodontol* 2012; **39**: 224–244.
16 Pjetursson BE, Zwahlen M, Lang NP. Quality of reporting of clinical studies to assess and compare performance of implant-supported restorations. *J Clin Periodontol* 2012; **39**: 139–159.
17 Schmidt JC, Sahrmann P, Weiger R, Schmidlin PR, Walter C. Biologic width dimensions–a systematic review. *J Clin Periodontol* 2013; **40**: 493–504.
18 Wennström JL, Dahlén G, Ramberg P. Subgingival debridement of periodontal pockets by air polishing in comparison with ultrasonic instrumentation during maintenance therapy. *J Clin Periodontol* 2011; **38**: 820–827.
19 Petersilka GJ, Steinmann D, Häberlein I, Heinecke A, Flemmig TF. Subgingival plaque removal in buccal and lingual sites using a novel low abrasive air-polishing powder. *J Clin Periodontol* 2003; **30**: 328–333.
20 Flemmig TF, Arushanov D, Daubert D, Rothen M, Mueller G, Leroux BG. Randomized controlled trial assessing efficacy and safety of glycine powder air polishing in moderate-to-deep periodontal pockets. *J Periodontol* 2012; **83**: 444–452.
21 Hägi TT, Hofmanner P, Salvi GE, Ramseier CA, Sculean A. Clinical outcomes following subgingival application of a novel erythritol powder by means of air polishing in supportive periodontal therapy: a randomized, controlled clinical study. *Quintessence Int* 2013; **44**: 753–761.
22 Flemmig TF, Hetzel M, Topoll H, Gerss J, Haeberlein I, Petersilka G. Subgingival debridement efficacy of glycine powder air polishing. *J Periodontol* 2007; **78**: 1002–1010.

23 Petersilka GJ, Tunkel J, Barakos K, Heinecke A, Häberlein I, Flemmig TF. Subgingival plaque removal at interdental sites using a low-abrasive air polishing powder. *J Periodontol* 2003; **74**: 307–311.

24 Kontturi-Närhi V, Markkanen S, Markkanen H. The gingival effects of dental airpolishing as evaluated by scanning electron microscopy. *J Periodontol* 1989; **60**: 19–22.

25 Mishkin DJ, Engler WO, Javed T, Darby TD, Cobb RL, Coffman MA. A clinical comparison of the effect on the gingiva of the Prophy-Jet and the rubber cup and paste techniques. *J Periodontol* 1986; **57**: 151–154.

26 Pelka M, Trautmann S, Petschelt A, Lohbauer U. Influence of air-polishing devices and abrasives on root dentin-an *in vitro* confocal laser scanning microscope study. *Quintessence Int* 2010; **41**: e141–e148.

27 Tada K, Wiroj S, Inatomi M, Sato S. The characterization of dentin defects produced by air polishing. *Odontology* 2012; **100**: 41–46.

28 Tada K, Kakuta K, Ogura H, Sato S. Effect of particle diameter on air polishing of dentin surfaces. *Odontology* 2010; **98**: 31–36.

29 Petersilka GJ, Bell M, Mehl A, Hickel R, Flemmig TF. Root defects following air polishing. *J Clin Periodontol* 2003; **30**: 165–170.

30 Finlayson RS, Stevens FD. Subcutaneous facial emphysema secondary to use of the Cavi-Jet. *J Periodontol* 1988; **59**: 315–317.

31 Josephson GD, Wambach BA, Noordzji JP. Subcutaneous cervicofacial and mediastinal emphysema after dental instrumentation. *Otolaryngol Head Neck Surg* 2001; **124**: 170–171.

32 Liebenberg WH, Crawford BJ. Subcutaneous, orbital, and mediastinal emphysema secondary to the use of an air-abrasive device. *Quintessence Int* 1997; **28**: 31–38.

33 Cadosch J, Zimmermann U, Ruppert M, Guindy J, Case D, Zappa U. Root surface debridement and endotoxin removal. *J Periodontal Res* 2003; **38**: 229–236.

34 von Troil B, Needleman I, Sanz M. A systematic review of the prevalence of root sensitivity following periodontal therapy. *J Clin Periodontol* 2002; **29**: 173–177; discussion 95-6.

35 Wolf HF, Rateitschak KH. *Farbatlanten der Zahnmedizin 1: Parodontologie*. Stuttgart, Germany: Georg Thieme Verlag, 2003.

36 Kocher T, Fanghanel J, Schwahn C, Rühling A. A new ultrasonic device in maintenance therapy: perception of pain and clinical efficacy. *J Clin Periodontol* 2005; **32**: 425–429.

37 Aronson R. The role of comfort and discomfort in insulin therapy. *Diabetes Technol Ther* 2012; **14**: 741–747.

38 Horning GM, Cobb CM, Killoy WJ. Effect of an air-powder abrasive system on root surfaces in periodontal surgery. *J Clin Periodontol* 1987; **14**: 213–220.

39 Matuliene G, Pjetursson BE, Salvi GE *et al.* Influence of residual pockets on progression of periodontitis and tooth loss: results after 11 years of maintenance. *J Clin Periodontol* 2008; **35**: 685–695.

40 Bäumer A, Pretzl B, Cosgarea R *et al.* Tooth loss in aggressive periodontitis after active periodontal therapy: patient-related and tooth-related prognostic factors. *J Clin Periodontol* 2011; **38**: 644–651.

41 Graetz C, Dorfer CE, Kahl M *et al.* Retention of questionable and hopeless teeth in compliant patients treated for aggressive periodontitis. *J Clin Periodontol* 2011; **38**: 707–714.

42 Wennström JL, Tomasi C, Bertelle A, Dellasega E. Full-mouth ultrasonic debridement versus quadrant scaling and root planing as an initial approach in the treatment of chronic periodontitis. *J Clin Periodontol* 2005; **32**: 851–859.

43 Ebell MH, Siwek J, Weiss BD *et al.* Strength of Recommendation Taxonomy (SORT): a patient-centered approach to grading evidence in the medical literature. *Am Fam Physician* 2004; **69**: 549–557.

44 Phillips B. GRADE: levels of evidence and grades of recommendation. *Arch Dis Child* 2004; **89**: 489.

45 Atkinson DR, Cobb CM, Killoy WJ. The effect of an air-powder abrasive system on *in vitro* root surfaces. *J Periodontol* 1984; **55**: 13–18.

46 Banerjee A, Hajatdoost-Sani M, Farrell S, Thompson I. A clinical evaluation and comparison of bioactive glass and sodium bicarbonate air-polishing powders. *J Dent* 2010; **38**: 475–479.

47 Boyde A. Airpolishing effects on enamel, dentine, cement and bone. *Br Dent J* 1984; **156**: 287–291.

48 de Boever JA, Van de Velde F. Aerosol-jet device for plaque removal. A clinical and scanning electron microscopy study. *Dtsch Zahnarztl Z* 1985; **40**: 725–729.

49 Glenwright HD, Knibbs PJ, Burdon DW. Atmospheric contamination during use of an air polisher. *Br Dent J* 1985; **159**: 294–297.

50 Holm G, Berger A, Henriksson E, Jonsson U, Rimen A. Air-Flow, a realistic alternative to polishing with rubber cups and paste. *Tandlakartidningen* 1985; **77**: 915–918.

51 Hunter KM, Holborow DW, Kardos TB, Lee-Knight CT, Ferguson MM. Bacteraemia and tissue damage resulting from air polishing. *Br Dent J* 1989; **167**: 275–278.

52 Janicki T, Sobczak-Kupiec A, Skomro P, Wzorek Z. Surface of root cementum following air-polishing with bioactive hydroxyapatite (Ca and P mapping). A pilot study. *Acta Bioeng Biomech* 2012; **14**: 31–38.

53 Kee-Nichol A. Air polishing technique and patient selection. *Dentalhygienistnews* 1990; **3**: 6.

54 Kontturi-Närhi V, Markkanen S, Markkanen H. Effects of airpolishing on dental plaque removal and hard tissues as evaluated by scanning electron microscopy. *J Periodontol* 1990; **61**: 334–338.

55 Kozlovsky A, Artzi Z, Nemcovsky CE, Hirshberg A. Effect of air-polishing devices on the gingiva: histologic study in the canine. *J Clin Periodontol* 2005; **32**: 329–334.

56 Logothetis DD, Gross KB, Eberhart A, Drisko C. Bacterial airborne contamination with an air-polishing device. *Gen Dent* 1988; **36**: 496–499.

57 Macfarlane DW. New hand instruments for subgingival scaling. *Br Dent J* 1974; **136**: 381–382.

58 Makinson OF. Air-polishing systems. Clinical notes no. 3. *Aust Dent J* 1985; **30**: 136.

59 Marumo Y, Suzuki A, Kimura S *et al.* Clinical evaluation of air polishing systems. *Shigaku* 1985; **73**: 124–144.

60 Newman PS, Silverwood RA, Dolby AE. The effects of an airbrasive instrument on dental hard tissues, skin and oral mucosa. *Br Dent J* 1985; **159**: 9–12.

61 Petersilka GJ. Subgingival air-polishing in the treatment of periodontal biofilm infections. *Periodontology* 2000 2011; **55**: 124–142.

62 Petersilka GJ, Schenck U, Flemmig TF. Powder emission rates of four air polishing devices. *J Clin Periodontol* 2002; **29**: 694–698.

63 Rateitschak-Plüss EM. Problems with subgingival scaling instruments and root planning. *Dtsch Zahnarztl Z* 1985; **40**: 715–720.

64 Rawson RD, Nelson BN, Jewell BD, Jewell CC. Alkalosis as a potential complication of air polishing systems. A pilot study. *Dent Hyg (Chic)* 1985; **59**: 500–503.

65 Rühling A, Schlemme H, König J, Kocher T, Schwahn C, Plagmann HC. Learning root debridement with curettes and power-driven instruments. Part I: a training program to increase effectivity. *J Clin Periodontol* 2002; **29**: 622–629.

66 Sauro S, Watson TF, Thompson I. Dentine desensitization induced by prophylactic and air-polishing procedures: an *in vitro* dentine permeability and confocal microscopy study. *J Dent* 2010; **38**: 411–422.
67 Snyder JA, McVay JT, Brown FH *et al*. The effect of air abrasive polishing on blood pH and electrolyte concentrations in healthy mongrel dogs. *J Periodontol* 1990; **61**: 81–86.
68 Stirrups DR. Methods of reducing bacterial contamination of the atmosphere arising from use of an air-polisher. *Br Dent J* 1987; **163**: 215–216.
69 Uchida T, Suda Y, Motohashi K, Suzuki A, Marumo Y, Yokozuka S. The effect of an air polishing system on orthodontic materials and tooth surfaces. *Shigaku* 1986; **74**: 377–390.
70 Van der Linde ES, Dreyer WP, Kühn IK, van Heerden JD. A comparative clinical study of an air polishing instrument. *J Dent Assoc S Afr* 1986; **41**: 453–456.
71 Worrall SF, Knibbs PJ, Glenwright HD. Methods of reducing bacterial contamination of the atmosphere arising from use of an air-polisher. *Br Dent J* 1987; **163**: 118–119.
72 Yanagimura M, Koike F, Satoh E, Wu CS, Hara K, Kawakami T. Application of an air-powder abrasive system in periodontal therapy and its effect on root surfaces. *Nihon Shishubyo Gakkai Kaishi* 1988; **30**: 1168–1179.
73 Yu X, An Y, Luan Q. Effects of bio-glass in subgingival scaling and root planing. *Beijing Da Xue Xue Bao* 2011; **43**: 40–43.

Supporting information

Additional supporting information may be found in the online version of this article.

Appendix S1. Excluded studies and reason for exclusion.
Appendix S2. Scores for assessment of risk of bias
Appendix S3. Risk of bias in individual studies.