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The efficacy of the adjunct use of subgingival air-polishing therapy with erythritol powder compared to conventional debridement alone during initial non-surgical periodontal therapy

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Abstract

Aim: To assess the efficacy of the adjunct use of a subgingival erythritol powder air-polishing device (EPAP) in comparison to conventional subgingival instrumentation alone during initial non-surgical periodontal therapy.

Materials and Methods: Twenty-one patients with generalized Stages 2 and 3 grade B periodontitis were included in this single centre, single blinded, split-mouth, randomized clinical trial. Teeth on the control side were treated with conventional hand and ultrasonic instrumentation, while those on the contralateral test side was treated using EPAP as adjunct to conventional subgingival instrumentation with hand and ultrasonic instruments. Three months after initial instrumentation, persisting pockets of ≥4 mm were re-treated, in both control and test sides, again with the respective treatment approach—subgingival instrumentation alone on control, and subgingival instrumentation + EPAP on test side. Clinical parameters such as probing pocket depth (PPD), bleeding on probing, and relative attachment level were recorded at baseline and 3 and 6 months following the initial instrumentation. Subgingival plaque samples were collected at baseline, immediately post surgery, as well as at 1 week, 1 month, 3 months, and 6 months after initial instrumentation.

Results: In the test group after 6 months, a significantly larger number of initially deep pockets (PPD ≥ 5.5 mm) were reduced to shallow (PPD ≤ 3.4 mm), and a larger attachment gain was observed. No statistically significant microbiological differences could be found between test and control group.

Conclusions: The results of the present study indicate that the adjunct use of subgingival airflow therapy with EPAP during initial non-surgical periodontal therapy might be beneficial in initially deep pockets (PPD ≥ 5.5 mm).

KEYWORDS
air polishing, debridement, erythritol, periodontitis, ultrasonics

Clinical Relevance

Scientific rationale for study: There is a lack of clinical and microbiological evidence justifying the use of erythritol powder air-polishing (EPAP) as an adjunct to conventional instrumentation in initial non-surgical periodontal therapy.

Principal findings: The adjunct use of EPAP may improve clinical parameters in initial non-surgical therapy of deep pockets (probing pocket depth [PPD] ≥ 5.5 mm); however, microbiological outcomes did not benefit from adjunctive EPAP.

Practical implications: The adjunct use of EPAP in initially deep (PPD ≥ 5.5 mm) pockets may improve clinical outcomes when used in initial non-surgical periodontal therapy of untreated patients with Stages 2 and 3 grade B periodontitis.

1 | INTRODUCTION

Current treatment of periodontitis involves removal of tooth deposits such as biofilm and calculus in order to achieve reduction of inflammation and probing depths (PDs; Claffey et al., 2004). In addition to conventional debridement, known as subgingival instrumentation, various adjunct treatment approaches such as laser, antimicrobials, or photodynamic therapy have been suggested to improve treatment outcomes (Sgolastra et al., 2013; Salvi et al., 2020). With the introduction of new low-abrasive and resorbable powders in combination with subgingival delivery tools, there has been renewed interest in exploring the potential of air-polishing devices (APDs) in periodontal treatment and maintenance. Currently, based on numerous studies, the use of APDs in periodontal therapy has been expanded significantly, allowing supra and subgingival debridement of tooth and root surfaces (Petersilka et al., 2008; Flemmig et al., 2012). APDs have been shown to help reduce post-operative patient discomfort and sensitivity, increased patient acceptance, less time-consuming treatment, and only minor alterations to surrounding soft and hard tissues (Moëne et al., 2010; Wennström et al., 2011). It has also been suggested that teeth with furcation involvement and sites with reduced access, which have traditionally been difficult to debride with conventional instrumentation, may benefit from air-flow therapy (Horning et al., 1987).

Initially, APDs were introduced to remove biofilm and stains from tooth enamel by spraying the surface with a slurry of compressed air, water, and powders containing abrasive particles. However, abrasive powders were shown to be detrimental to exposed root surfaces, gingiva, and some restorative materials. Therefore, resorbable powders with low abrasiveness, such as glycine and erythritol, were introduced (Hägi et al., 2013).

The newly introduced erythritol powder is a water-soluble, nontoxic sugar alcohol and artificial sweetener used in the food industry. The commercially available erythritol powder has a mean particle size of 14 μm and can be used for supra and subgingival removal of biofilm and stains (Air-flow Plus, EMS, Electro Medical Systems, Nyon, Switzerland). Erythritol powder air-polishing (EPAP) as monotherapy has demonstrated comparable outcomes during supportive periodontal therapy to conventional power-driven and manual debridement (Hägi et al., 2013, 2015; Müller et al., 2014).

It has been suggested that erythritol powder itself may have long-term antimicrobial effect on the subgingival biofilm. In vitro, erythritol demonstrated a dose-dependent reduction of keystone periodontal pathogen *Porphyromonas gingivalis* up to a plateau concentration. The same study indicated that erythritol might inhibit biofilm by reducing extracellular matrix production via RNA and DNA depletion and alteration of amino acid metabolism of *P. gingivalis* and *Streptococcus gordonii* (Hashino et al., 2013). In addition to erythritol, glycine has also been shown to reduce the numbers of *P. gingivalis* and *Aggregatibacter actinomycetemcomitans* during supportive periodontal treatment (Flemmig et al., 2012; Müller et al., 2014).

Some recent studies have suggested that there might be an additional benefit of the combined use of APDs with conventional instrumentation in the initial treatment of periodontitis (Tsang et al., 2018; Zhang et al., 2021).

However, a study by Kargas et al. (2015), which compared APD treatment using glycine powder as a monotherapy with conventional instrumentation, found significantly greater residual PDs at all time points in the APD group. This indicates that APD does not have sufficient capability to remove mineralized deposits, and so replacement of the conventional treatment by APD monotherapy in non-treated periodontitis cases is not justified.

Although most previous studies explored the efficacy of glycine, there is only scarce evidence regarding the clinical and microbiological effects of erythritol powder in conjunction with APD during initial periodontal therapy (Park et al., 2018). Furthermore, there is lack of evidence regarding the effect of adjunct use of APD with erythritol powder in combination with conventional treatment compared to conventional treatment alone in non-treated periodontitis cases. It would also be of clinical interest to see if the adjunct use of APD has different effects depending on initial PDs.

Therefore, the aim of the present study was to investigate the effect on clinical and microbiological parameters of the combination of erythritol powder APD with conventional instrumentation (EPAP + subgingival instrumentation) compared to conventional subgingival instrumentation alone during initial non-surgical therapy in patients with generalized Stages 2 and 3 grade B periodontitis.

2 | MATERIALS AND METHODS

The present prospective, split-mouth, single-centre, examiner-blinded, randomized clinical trial was conducted at the Department of Periodontics, Sydney Dental Hospital, University of Sydney, Australia,

during 2017–2019. Laboratory analysis was performed at the Institute of Dental Research, Westmead Hospital, Australia. The study was approved by the Ethical Committee and registered with Australia and New Zealand Clinical Trials Registry (ANZCTR Registration Number: ACTRN12617000128392). All participants were informed about the procedures and signed a consent form before participating in the study.

2.1 | Subjects and randomization

Power calculation for statistical significance produced a required cohort of 17 participants. Power analysis was done for the outcome of PD and used a simulation approach. Random data samples were generated in various sizes taking account of the nested structure of the data. Models were fit, and the proportion of models in which a significant result ($p < .05$) for treatment was observed was equivalent to the power. One thousand simulations were carried out for each proposed sample size.

The simulations showed that measuring one matched pair of teeth in each of 17 patients (power = 0.8) or measuring two matched pairs in each of 9 patients (power = 0.84) would be sufficient to detect a mean difference of 1 mm in PD, which can be of clinical relevance. Power is driven by the number of pairs of teeth measured, rather than the number of patients, so measuring three pairs of teeth in six patients would also give a power of 0.8 for detecting a difference of 1 mm.

A total of 21 participants (7 males, 14 females) were recruited and preliminarily assessed for eligibility considering a risk of 10% dropout. The participants were included on the basis of the following criteria: over 18 years of age; in good systemic health; with generalized Stages 2 and 3 periodontitis; and retaining more than 20 teeth equally distributed in all quadrants with a minimum of six teeth per quadrant. Approximal plaque index (API; Lange, 1975) of ≤35% and a sulcus bleeding index (SBI; Muhlemann, 1971) ≤25% were prerequisites to participate in the study. Patients unable to maintain sufficient oral hygiene were also excluded from the study.

The new classification system recommends the personalization of periodontal treatment according to the different categories established (Papapanou et al., 2018). This includes, according to the consensus statement of the 6th European Workshop, the use of systemic antimicrobials in periodontitis patients that should be restricted to certain patients and periodontal conditions such as severe and progressing forms of periodontitis. Therefore, patients with grade C periodontitis were excluded from this study because of their possible need for adjunct treatment with systemic antibiotics due to rapid clinical attachment loss (CAL) progression, as well as their need for possible surgical intervention following the non-surgical treatment (Heitz-Mayfield et al., 2002).

Further exclusion criteria included smoking, pregnancy and lactation, allergy to erythritol or chlorhexidine, and presence of any serious and uncontrolled systemic diseases. In addition, history of any previous subgingival instrumentation or the use of antibiotics in the last 3 months excluded participation in the study.

In each patient, one upper and one lower quadrant on the same side were assigned to test, and the contralateral upper and lower quadrants were assigned to control treatment by tossing a coin. The test and control quadrants (sides) were recorded and concealed by the treating clinician. All clinical measurements and subgingival plaque sampling were conducted by the same blinded investigator.

2.2 | Clinical protocol

Before commencement of the study, participants were provided oral hygiene instructions and supragingival debridement following standard clinical protocol. Alginate impressions were taken to produce vacuum-moulded acrylic stents for precise and reproducible recording of the relative attachment level (RAL).

The following clinical parameters were assessed at six sites of each tooth at baseline as well as after 3 and 6 months: probing pocket depth (PPD), bleeding on probing (BOP), and RAL. RAL was measured from the fixed reference of the customized acrylic stent. All clinical measurements were performed using a Florida Probe (Florida Probe Corporation, Gainesville, FL) by a well-trained clinician. The quality of oral hygiene of each patient was monitored throughout the entire study by assessing the API and SBI.

Test treatment was initiated with the APD (Electro Medical Systems) using the AIR-FLOW PROPHYLAXIS MASTER in combination with erythritol powder (AIR FLOW Powder PLUS, mean grain size 14 μm, 0.3% chlorhexidine). At the beginning of the treatment, all sites in the test quadrants were treated with the AIR-FLOW handpiece using the spray-painting stroke technique. Afterwards, each pocket of ≥5 mm was treated with the PERIO-FLOW handpiece in combination with a flexible disposable nozzle (PERIO-FLOW nozzle) using vertical overlapping strokes for about 5 s per surface. The application of the APD in the test quadrants was performed as a first operative step, according to the manufacturer's instructions, to reduce the risk of air emphysema (Petersilka, 2011; Mensi et al., 2021; Petersilka et al., 2021). Powder settings used were 70% (AIR-FLOW) and 50% (PERIO-FLOW), and water setting was 80%. The powder chamber was filled and kept according to manufacturer's instructions.

After completion of APD, pockets ≥4 mm were subgingivally debrided using the piezo device included in the PROPHYLAXIS MASTER (AIR-FLOW) according to manufacturer's instructions. Afterwards, hand curettes (Hu-Friedy, Chicago, IL) were used until the operator considered the surfaces to be sufficiently clean and free of deposits.

The contralateral control quadrants received conventional treatment with the combination of ultrasonic and hand instrumentation only. Pockets ≥4 mm were subgingivally debrided using the piezo device according to manufacturer's instructions, and hand curettes were used until the operator considered the surfaces to be sufficiently clean and free of deposits.

Test and control treatments were carried out under local anaesthesia and were performed by the same operator, who was a well-trained periodontist, within 12 h.

Non-surgical re-treatment at 3 months after initial treatment was conducted in still active pockets with PPD of ≥4 mm and signs of inflammation as well as pockets where persisting subgingival deposits were detected during re-evaluation after 3 months using the same experimental protocol as described above for the test and control quadrants.

Therefore, clinical parameters were recorded at baseline and at 3 and 6 months following the initial treatment.

2.3 | Microbiological sampling and analysis

Subgingival plaque samples were collected from the four deepest sites in test and control quadrants using sterile paper points (ISO 40, Roeko GmbH & Co. KG, Langenau, Germany). Before sampling, the selected sites were isolated with cotton rolls and air-dried. A sterile paper point was inserted into the selected pocket for 10 s. Immediately after sampling, the paper points were placed in an Eppendorf tube (Eppendorf, Hamburg, Germany) containing 100 µl of Beads solution and were stored at −80°C until processing. Microbiological samples were taken at baseline, immediately after the instrumentation, and at 1 week, 1 month, 3 months, and 6 months following therapy.

After the plaque samples were thawed to room temperature, bacterial DNA extraction was performed using the QIAamp DNA Mini Kit (Qiagen, Hilden, Germany) according to the manufacturer's instructions.

Bacterial quantification was performed using quantitative real-time polymerase chain reaction (qPCR) following a procedure designed for the identification of *P. gingivalis* (Nadkarni et al., 2009). TaqMan primers/probes were used against the target universal 16s RNA and *P. gingivalis* 16s RNA on a Mx3000P real-time PCR system (Stratagene, Agilent Technologies, Mulgrave, Australia) using the 5× HOT FIREPol probe qPCR Mix (Solis BioDyne, Tartu, Estonia). The amplification of DNA was done under the following conditions: 95°C for 15 min, followed by 40 cycles of 95°C for 20 s and 60°C for 1 min. Fluorescence intensities were compared against a passive fluorophore (ROX) present in the Mastermix using a standard curve to obtain quantitative readings in picograms. Subsequently, the ratio *P. gingivalis* 16s/universal 16s was calculated and analysed.

2.4 | Statistical analysis

All variables were compared within the individual. The primary outcome variable was reduction in number of sites with PPD ≥3.5 mm. Secondary variables included changes in BOP, RAL, and the median for the ratio of *P. gingivalis* to total bacteria.

Mean trajectories of the primary outcomes were modelled using linear (or logistic for BOP) mixed models with random intercepts for patients and teeth. The models included group, time point (as categorical variable), and interaction between group and time. Significance of the group: time point interaction terms were examined as the difference between trajectories for the two groups. Analysis was carried out in R 3.5 using the lme4 package for model fitting.

TABLE 1 Basic characteristics

Subjects	20
Females, males	13, 7
Mean age (years)	60.24 (12.2)
Mean number of teeth	26.4 (2.9)
Mean API (%)	23.55 (9.1)
Mean SBI (%)	19.62 (9.8)
PPD sites (*n*)	
Deep (PPD ≥ 5.5 mm) sites	
Test	72 (4.5%)
Control	64 (3.9%)
Moderate (PPD = 3.5–5.4 mm) sites	
Test	287 (17.8%)
Control	249 (15.2%)
Shallow (PPD ≤ 3.4 mm) sites	
Test	1254 (77.7%)
Control	1328 (80.9%)

Note: SD is shown in parenthesis.
Abbreviations: API, approximal plaque index; PPD, probing pocket depth; SBI, sulcus bleeding index.

The ratio of *P. gingivalis* to total bacteria was summarized by median and interquartile, and differences between control and treatment at each time point were assessed by Wilcoxon tests. Difference from baseline at each time point was also assessed separately for control and test groups using Wilcoxon tests.

To investigate the PD-dependent effect of air-flow debridement, periodontal pockets at the test and control sides were also categorized into different severity groups according to PPD: all periodontal pockets (PPD ≥ 3.5 mm), shallow pockets (PPD ≤ 3.4 mm), moderate pockets (PPD 3.5–5.4 mm), and deep pockets (PPD ≥ 5.5 mm) (Lindhe, Nyman, et al., 1982; Heitz-Mayfield & Lang, 2013).

3 | RESULTS

Patients were recruited between January and November 2017 and were followed up until June 2019. A total of 21 participants were recruited, which satisfied the power calculation including dropouts. One patient moved interstate and was considered a "dropout." Therefore, 20 participants completed the clinical trial. Their baseline characteristics are given in Table 1, with no "intention to treat" analysis.

Out of 20 participants, 85% were diagnosed as Stage 3 and 25% as Stage 2 periodontitis. All participants were grade B, as per the most recent classification system (Caton et al., 2018).

There were no significant differences between test and control groups at baseline in any of the clinical variables ($p > .01$).

Of the 1613 sites in the test group, there were 359 (22%) that had PPD ≥3.5 mm and required treatment. In the control group, 313 (19%) out of 1641 were treated. All test and control sites were further classified into deep (PPD ≥ 5.5 mm), moderate (3.5–5.4 mm), and shallow (PPD ≤ 3.4 mm) according to their PPD and monitored

TABLE 2 Changes in clinical parameters compared with baseline and between groups at each time point

	Baseline	3 months	*p*-Value†	6 months	*p*-Value†
Mean PD (mm)					
Test	2.7 (1.4)	2.1 (1.2)	<.001*	2.0 (1.1)	<.001*
Control	2.6 (1.3)	2.1 (1.2)	<.001*	2.1 (1.1)	<.001*
p-Value‡	.22	.97		.99	
Mean RAL (mm)					
Test	2.9 (2.7)	2.1 (2.4)	<.001*	2.0 (2.3)	<.001*
Control	2.8 (2.6)	2.1 (2.4)	<.001*	2.1 (2.3)	<.001*
p-Value‡	.11	.47		.78	
Mean BOP (%)					
Test	30.1 (16.7)	14.3 (13.9)	.003*	12.9 (6.6)	<.001*
Control	24.5 (19.0)	11.4 (8.6)	.009*	12.5 (8.0)	.01*
p-Value‡	.33	.43		.85	
Mean API (%)					
Test	23.79 (8.29)	20.68 (11.17)	.706	21.91 (21.91)	.428
Control	23.30 (9.85)	22.23 (11.98)	.146	21.16 (13.70)	.548
p-Value‡	.761	.177		.668	
Mean SBI (%)					
Test	20.75 (11.33)	13.84 (9.14)	.002*	12.40 (9.88)	.095
Control	19.12 (8.30)	11.14 (7.74)	.028*	13.64 (11.74)	.006*
p-Value‡	.618	.133		.428	

Abbreviations: API, approximal plaque index; BOP, bleeding on probing; PD, probing depth; RAL, relative attachment level; SBI, sulcus bleeding index.

†*p* versus baseline.

‡*p* test versus control.

**p* < .05.

for 6 months. Of the sites requiring periodontal treatment (PPD ≥ 3.5 mm), 4.5% in test and 3.9% in control group were classified as deep and 17.8% in test and 15.2% in control group were classified as moderate pockets (Table 1).

Basic characteristics, demographics, and distribution of pockets are outlined in Table 1. All patients attended their appointments as per the study protocol. No adverse effects were reported.

As shown in Table 2, it is evident that the clinical parameters PD, RAL, and BOP had significantly improved at 3 and 6 months in comparison to baseline. All these improvements compared to baseline were statistically significant ($p < .05$). In the test group, there was a PPD reduction compared to baseline of 0.6 mm after 3 months and 0.7 mm after 6 months, compared to the control group with a 0.5 mm PPD reduction after 3 and 6 months. The relative attachment gain in the test group compared to baseline was 0.8 mm after 3 months and 0.9 mm after 6 months compared to the control group with 0.7 mm of relative attachment gain after 3 and 6 months. Similar to the findings regarding PPD and RAL, there was a significant reduction of BOP in both test and control groups at 3 and 6 months compared to baseline. However, the inter-group comparison did not show any statistically significant difference between the test and control groups at any of the chosen time points.

Oral hygiene indices (API and SBI) remained stable throughout the entire observation period, reflecting good patient compliance with oral hygiene.

To investigate the PD-dependent effect of APD treatment, we classified all PDs into deep (PPD ≥ 5.5 mm), moderate (3.5–5.4 mm), and shallow (PPD ≤ 3.4 mm). A separate analysis of the groups with shallow or moderate pockets did not reveal any statistically significant differences between test and control treatment. However, a separate investigation of the group with initially deep pockets (PPD ≥ 5.5 mm) showed significant differences between the conventional treatment alone and the combination of APD and conventional treatment. Table 3 shows the clinical changes regarding PPD and RAL at 3 and 6 months in initially deep pockets (PPD ≥ 5.5 mm).

Whereas in the test group, 39 of the initially 72 deep pockets at baseline could be reduced to shallow pockets after 6 months, this was possible only in 18 pockets of the initially 64 deep pockets in the control group. This difference between the test and control group was statistically significant ($p = .00359$). Furthermore, in the group with initially deep pockets there was a relative attachment gain of 3.26 mm in the test group compared to 1.72 mm in the control group.

This difference in attachment gain between the test and control groups was also statistically significant ($p = .00951$).

At both 3 and 6 months, the number of test sides with less than 10% BOP was significantly higher than that at baseline. This could not be observed for the control sides. However, inter-group comparison did not show any statistically significant difference between the test and control sides (data not shown).

TABLE 3 Deep sites from baseline to 6 months: prevalence and relative attachment level (RAL) (gain)

	Baseline (*n*) deep sites (PPD ≥ 5.5 mm)	Three months (*n*) deep sites reduced to shallow (PPD ≤ 3.4 mm)	$p^{\dagger}$	Six months (*n*) deep sites reduced to shallow (PPD ≤ 3.4 mm)	$p^{\dagger}$
Test	72	28	<.001*	39	<.001*
Control	64	18	<.001*	18	<.001*
$p^{\ddagger}$	.408	.304		.00359*	
	Baseline RAL (mean)	**3 months RAL gain (mean)**		**6 months RAL gain (mean)**	
Test	7.33	2.95	<.001*	3.26	<.001*
Control	7.27	2.05	<.001*	1.72	<.001*
$p^{\ddagger}$	.27	.791		.00951*	

Abbreviations: *n*, number of sites; PPD, probing pocket depth.
$^{\dagger}p$ versus baseline.
$^{\ddagger}p$ test versus control.
*$p < .05$.

TABLE 4 Median (interquartile range) for ratio of *P. gingivalis* to total bacteria (×100,000)

	Baseline	Post-treatment	$p^{\dagger}$	1 week	$p^{\dagger}$	1 month	$p^{\dagger}$	3 months	$p^{\dagger}$	6 months	$p^{\dagger}$
Treatment	2.5 (0.4–9.1)	2.0 (1.2–4.4)	.61	0.2 (0.01–3.5)	.13	0.7 (0.1–3.3)	.20	0.1 (0.02–0.6)	.05	0.6 (0.1–0.8)	.34
Control	1.4 (0.2–4.5)	1.1 (0.2–2.9)	.32	0.2 (0.03–1.8)	.06	0.2 (0.02–1.1)	.14	0.6 (0.01–2.0)	.22	0.8 (0.3–2.2)	.11
$p^{\ddagger}$	.96	.46		.76		.40		.57		.30	

$^{\dagger}p$ versus baseline.
$^{\ddagger}p$ test versus control.

To evaluate the adjunct use of air-flow therapy, multi-rooted teeth with furcation involvement were also analysed as a separate group. Overall, there were 229 sites with PPD ≥3.4 mm in the test group and 204 sites with PPD ≥3.4 mm in the control group that required treatment.

Although there was a significant reduction of PPD in each group at each time point compared to baseline, there was no statistically significant difference between the test and control groups. The same was observed regarding BOP in furcation areas. There was significant reduction in each group between each time point and baseline but no statistically significant difference between the test and control groups (data not shown).

3.1 | Microbiological results

The ratio of the number of *P. gingivalis* to number of total bacteria did not show any statistically significant difference between the test and control groups at any time point (Table 4).

4 | DISCUSSION

The present study was conducted as a randomized, split-mouth, single-blinded, clinical trial to limit the number of factors impacting the outcomes of the study. The split-mouth design was chosen to reduce inter-individual variability from the estimates of the treatment effect (Lesaffre et al., 2009). Furthermore, all clinical measurements were recorded using a calibrated computerized probe, and RAL was measured using an acrylic stent as reference point to reduce measurement variability. The use of the Florida probe resulted in increased reproducibility as well as accuracy and, when paired with an acrylic stent, provided a standard deviation of at most 0.28 mm (Gibbs et al., 1988). Real-time qPCR was selected for the microbiological analysis since it had demonstrated in numerous studies excellent detection limits and very little cross-reactivity under optimal conditions (Ng et al., 2018).

All patients achieved successful outcomes from both treatment modalities and significant reduction of the clinical parameters (PPD, BOP, and RAL). The clinical improvements were comparable to those achieved in traditional studies (Nordland et al., 1987). In the present study, no side effects were reported by any patient.

Different terms have been used in the literature to describe the adjunct treatment modality used in the present study. However, neither air-polishing nor air-abrasion really describes the mode of action or goal of this treatment device. A slurry of compressed air, water, and powder neither polishes the treated surface nor is it supposed to abrade hard or soft tissues of the tooth or the tooth-supporting apparatus. The goal, rather, is to remove biofilm or stains without causing damage to the tissues. Therefore, the term "air-flow debridement" would be more suitable to describe the mode of action and will be used for the following discussion. Multiple studies have shown that air-flow debridement can be effective in supportive periodontal therapy (Müller et al., 2014; Sekino et al., 2020; Petersilka et al., 2021). However, there is a lack of evidence regarding the effect of the adjunct use of air-flow debridement with erythritol powder in

combination with conventional treatment in non-treated periodontitis cases.

Therefore, the aim of the present study was to explore whether any clinical and microbiological beneficial effect can be obtained while combining EPAP and subgingival instrumentation during initial non-surgical periodontal therapy in patients with generalized Stages 2 and 3 periodontitis. All sites in the test quadrants were treated with the AIR-FLOW handpiece. Afterwards, each pocket of ≥5 mm was treated with the PERIO-FLOW handpiece in combination with the nozzle. After completion of APD, pockets ≥4 mm were subgingivally debrided using the piezo device and hand instruments. In the contralateral control quadrants, pockets ≥4 mm received conventional treatment with subgingival debridement using a combination of the piezo device and hand curettes.

This included initial treatment of all pockets with PPD ≥4 mm as well as re-treatment of persisting pockets after 3 months. The re-treatment was conducted in still active pockets with PPD of ≥4 mm and signs of inflammation as well as in pockets where persisting subgingival deposits were detected during re-evaluation after 3 months (Rosling et al., 2001; Matuliene et al., 2008).

To investigate any PD-dependent effect of air-flow debridement, all periodontal pockets were clustered to different groups: deep (PPD ≥ 5.5 mm), moderate (3.5–5.4 mm), and shallow (PPD ≤ 3.4 mm) (Lindhe, Socransky, et al., 1982; Heitz-Mayfield & Lang, 2013).

In the present study, at baseline, there was no statistically significant difference between the test and control groups in any of the assessed parameters. Considering all periodontal pockets, both treatment modalities showed statistically significant improvements in the clinical parameters PPD, BOP, and RAL at both 3 and 6 months compared to baseline. However, no statistically significant differences could be observed between the test and control groups considering all periodontal pockets at any time point. This is in accordance with recently published studies (Park et al., 2018; Jentsch et al., 2020; Zhang et al., 2021). Zhang et al. (2021) compared conventional treatment versus the combination of subgingival air-flow debridement using glycine powder and conventional treatment. Furthermore, they also investigated whether air-flow application before or after conventional treatment had any impact on the treatment outcome. However, all groups showed similar improvements in PPD reduction after 6 weeks and 3 months. No comments were made regarding attachment level changes. In the present study, air-flow debridement was used before the conventional treatment according to the manufacturer's instructions to reduce the risk of emphysema.

Tsang et al. (2018) compared the combination of subgingival air-flow therapy using glycine powder—and conventional treatment with the combination of subgingival instrumentation and air-water flushing. Only sites with initial PPD ≥5 mm at baseline received further air-flow treatment or air-water flushing. Both groups showed significant improvement after 6 months. However, there was no statistically significant difference between the test and control groups. Regarding CAL changes, no statistically significant differences could be found between any time points including the baseline in either the test or control group. Similar to the present study, Jentsch et al. (2020) compared the combination of subgingival air-flow therapy using erythritol powder (EPAP) and conventional subgingival instrumentation with subgingival instrumentation alone. After 3 and 6 months, both groups showed significant PPD reduction and clinical attachment gain compared to baseline without any statistically significant difference between the groups.

Mensi et al. (2021) also, when comparing the combination of EPAP and subgingival instrumentation with subgingival instrumentation alone, found no statistically significant differences between the groups regarding PPD reduction and CAL gain. However, there were various differences in their study design compared to ours. These include split-mouth versus parallel study design, patient selection criteria regarding smoking status and grade of periodontitis, type of instrumentation and observation period, and re-treatment.

To investigate any PD-dependent effect of air-flow therapy, in the present study all periodontal pockets were clustered to three severity groups, namely deep (PPD ≥ 5.5 mm), moderate (PPD 3.5–5.4 mm), and shallow (PPD ≤ 3.4 mm). In both groups with shallow and moderate pockets, no statistically significant difference in PPD or RAL could be observed between test and control treatment. However, in the severity group with initially deep pockets (PPD ≥ 5.5 mm), the test group showed significant reduction in the number of deep pockets (PPD ≥ 5.5 mm) and their conversion to shallow ones (PPD ≤ 3.4 mm) at 6 months. This may indicate a resolution of the periodontal pocket and establishment of a stable periodontal condition that will presumably favour long-term success and survival. Furthermore, the combination EPAP and subgingival instrumentation also showed significantly more RAL gain (3.26 mm) after 6 months compared to the conventional subgingival instrumentation alone (1.72 mm). The outcomes in the deep severity group indicate that the adjunct use of subgingival airflow therapy with EPAP during initial treatment as well as re-treatment of persisting pockets might be beneficial for initially deep pockets (PPD ≥ 5.5 mm). These clinical findings are in accordance with the study results of Jentsch et al. (2020), who also found significantly lower number of sites with PPD ≥5.5 mm in the EPAP test group after 6 months compared to the control.

A possible explanation for this could be that the adjunct application of EPAP removes the biofilm in areas that are mostly inaccessible for conventional instrumentation, such as root indentations or concavities, rough root surfaces, or soft tissue pocket walls, and may also remove more of the non-attached biofilm. Furthermore, microbiological studies have shown that different periodontal pathogens predominantly colonize specific areas of the pockets. Noiri and Ebisu (2000) and Noiri et al. (2001) showed that *Prevotella nigrescens* and *P. gingivalis* tend to be located at the epithelium-associated biofilm in the middle pocket zone. *Campylobacter rectus*, *Treponema denticola*, and *Fusobacterium nucleatum* are predominantly found in both the middle and deep pocket zones, with *C. rectus* present in both attached and unattached biofilm and *T. denticola* and *F. nucleatum* mainly located in the unattached biofilm.

To evaluate the adjunct use of air-flow therapy on teeth with furcation involvement, teeth with furcation defects were also analysed as a separate group regarding PPD and BOP reduction. However, although there was significant reduction in both PPD and BOP at all time points compared to baseline, inter-group comparison did not show any statistically significant differences. This indicates that the

adjunct use of air-flow treatment does not provide any additional benefit in teeth with furcation involvement. These findings are in accordance with those of other clinical studies where erythritol or glycine powder was used as a monotherapy in SPT and compared with conventional subgingival instrumentation (Petersilka et al., 2021; Ulvik et al., 2021). The nozzle used in our and these studies was not specifically designed to access subgingival furcation areas, and perhaps more time should be spent for thorough decontamination, considering the narrow access and complex anatomy of furcation (Ulvik et al., 2021).

The microbiological analysis in the present study failed to detect any statistically significant differences between the test and control groups regarding microbiological counts and the ratio of *P. gingivalis* in subgingival biofilm. This finding is in accordance with those of Jentsch et al. (2020), who could not detect any statistically significant microbiological differences either. However, despite no statistically significant clinical differences between test and control, Park et al. (2018) reported a significant decrease in *P. gingivalis* 1 month after treatment in the test group with adjunct EPAP. After 3 months, this difference was no longer statistically significant. Zhang et al. (2021) also indicated some reduction of *P. gingivalis* due to the adjunct use of glycine powder. However, overall, there was no significant difference in bacterial concentration at 3 months after treatment between the test and control groups. One possible reason for these differences between the studies could be variations in the prevalence of deep pockets. Since both the present study and Jentsch et al.'s (2020) showed the observed beneficial clinical effects of the adjunct use of subgingival EPAP in deep pockets only, it would be interesting to analyse the microbiological changes in these deeper pockets separately. Unfortunately, in the present study the subgingival samples were pooled and therefore this was not possible. However, this aspect should be addressed in future studies.

5 | CONCLUSION AND LIMITATIONS

This study has several limitations: for example, the absence of a control group with AIR-FLOW and PERIO-FLOW nozzles but without air-abrasive powder, and the limited sample size. Although the sample size was sufficient for statistical analyses, a larger sample size might have more clearly demonstrated the differences between the chosen treatment modalities, particularly those that just failed statistical significance. Furthermore, a larger number of multi-rooted teeth will be necessary to evaluate the effect of the adjunct use of APD in furcation areas. From a microbiological perspective, a larger sample size as well as the detection of additional periodontal pathogens will be required to evaluate the microbiological effect of the adjunct use of APD.

The results of the present study indicate that the adjunct use of subgingival airflow therapy with erythritol powder in combination with conventional subgingival debridement during initial non-surgical periodontal therapy in patients with Stages 2 and 3 periodontitis overall has no adjuvant effect on the clinical and microbiological parameters; however, it might provide some clinical benefits in the treatment of initially deep pockets (PPD ≥ 5.5 mm).

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Tihana Divnic-Resnik performed patient treatment and microbial analysis; Harold Pradhan recorded clinical parameters and collected microbial samples; and Axel Spahr supervised the research and corresponded. All authors were responsible for the study design and preparation of the manuscript.

ETHICS STATEMENT

Ethics approval from the Royal Prince Alfred Hospital Ethics of the Sydney South Eastern Local Health District committee was obtained (HREC/16/RPAH/633) and the research was conducted according to the principles outlined in the Declaration of Helsinki on human medical experimentation.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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