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Air-Flowing and Plaque Disclosing for Professional Biofilm Removal in Paediatric Patients: A Randomized Controlled Clinical Trial of Four Techniques

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ABSTRACT

Introduction: Professional Mechanical Plaque Removal (PMPR) in paediatric patients can be challenging due to limited cooperation and access. The use of plaque disclosing agents (PD) in combination with air-flowing devices employing low-abrasiveness powders has demonstrated improved plaque removal in adults, with additional advantages in terms of comfort and treatment efficiency. This randomized controlled clinical trial evaluated the residual plaque area (RPA) on anterior vestibular sextants after PMPR with and without PD and erythritol-based air-flowing (AF) in children. Secondary outcomes included post-treatment Full Mouth Plaque Score (FMPS), treatment duration and feedback from both patients and the clinicians.

Methods: A total of 120 children aged 6–12 years were randomized to one of four groups: air-flowing with plaque disclosing (AF + PD), air-flowing alone (AF), rubber cup and polishing paste with plaque disclosing (CUP + PD) or rubber cup and polishing paste alone (CUP). After treatment, PD was reapplied, FMPS was recorded and RPA was assessed via computer-assisted photographic analysis. Treatment time was measured and feedback from patients and clinicians was collected via structured questionnaires.

Results: AF + PD achieved significantly lower RPA—on anterior vestibular sextants—and FMPS values compared with all other methods. CUP took significantly less time but was the least effective for plaque removal. Although all approaches were rated positively, both children and clinicians expressed a preference for AF-based methods.

Conclusion: The combination of plaque disclosing and air-flowing significantly enhances plaque removal in paediatric patients, while improving the treatment experience for both patients and clinicians. AF + PD may represent a valuable adjunct to paediatric preventive protocols.

Trial Registration: ClinicalTrials.gov identifier: (NCT06765343)

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1 | Introduction

Dental plaque is a complex biofilm and the primary etiological factor for the most common oral diseases in childhood, including caries and gingivitis, and it may also contribute to early manifestations of periodontal disease [1, 2]. Although dental caries has traditionally been the main focus of paediatric preventive dentistry, epidemiological evidence indicates that gingivitis is nearly universal among school-aged children and adolescents, with a prevalence comparable to or even greater than that of caries [3]. While often considered a reversible and relatively benign condition, chronic plaque-induced inflammation established early in life may create a pro-inflammatory environment in the periodontal tissues, increasing susceptibility to breakdown later in life [3, 4]. These findings highlight the importance of effective plaque control in paediatric patients, not only for the immediate prevention of caries and gingival inflammation, but also for safeguarding long-term oral health.

Professional Mechanical Plaque Removal (PMPR) is a cornerstone of preventive strategies in children, complementing dietary counselling, reinforcement of home oral hygiene, and topical fluoride application [5–8]. However, its delivery in young patients is often challenging due to restricted oral access, small dentition size, and variable cooperation [9, 10]. As a result, there is a clear need for prophylactic approaches that are both efficient and well accepted by children.

The pattern of dental attendance is also a determinant of Early Childhood Caries (ECC) prevention [11, 12]. Yet, dental fear and anxiety remain highly prevalent—reported in up to 29.3% in children—frequently resulting in uncooperative behaviour, that hinders care and increases the risk of morbidity [9, 10, 13]. Delivering PMPR that is effective, time-efficient, and comfortable is therefore of major importance in the paediatric practice [12].

Traditionally, plaque removal in children has been performed using mechanical instruments, particularly rotating rubber cups with polishing paste, supplemented by ultrasonic or manual instrumentation when hard deposits are present. More recently, devices that utilize a jet of air, water and low-abrasiveness powders such as erythritol have gained popularity. In adults, these have been shown to effectively remove biofilm and plaque in the management of gingivitis [14, 15], during periodontal supportive therapy [16] and in the maintenance of dental implants [17]. This technique, historically termed as ‘air-polishing’, has been redefined as ‘air-flow debridement’ or ‘air-flowing’, reflecting its primary goal of minimally invasive plaque and stains removal rather than surface polishing [17, 18]. When performed with appropriate technique and powders, studies report minimal or no adverse effects on enamel, dentine, restorative materials, or soft tissues [19–22]. Additional advantages over conventional scaling and root planning in adult populations include time-efficiency, improved patient comfort and compliance, and higher clinician satisfaction [14, 15, 17, 23].

Plaque disclosing agents are another well-established tool with proven benefits in patient and parental education and motivation for oral hygiene improvement [24–26], as well as

in enhancing caries risk assessment [27]. More recently, disclosing agents have been shown to improve home oral care outcomes in periodontal patients [28], and to enhance professional plaque removal in both adults [29] and children [30], by improving visualization of deposits.

Based on this rationale, the present study aimed to assess the efficacy of combining a plaque disclosing agent (PD) with air-flowing (AF) during routine prophylaxis in paediatric patients with residual plaque area (RPA) on anterior vestibular sextants as the primary outcome. Secondary outcomes included post treatment plaque scores, treatment duration and feedback form both patients and clinicians.

2 | Materials and Methods

2.1 | Study Design

The present study is a single-blind, parallel, randomized, monocentric, controlled prospective clinical trial. The protocol was approved by the local University/Hospital ethical committee (protocol number N5675) and registered on clinicaltrials.gov (NCT06765343). The study was conducted in accordance with the principles of the Declaration of Helsinki [31] and reported following CONSORT PRO guidelines (Consolidated Standards of Reporting Trials) [32].

2.2 | Population

One hundred and twenty participants were recruited from the population attending the Paediatric Unit of Dentistry of the Spedali Civili of Brescia from March 2023 to July 2024 according to the following criteria:

- Systemically healthy;
- Age between 6–12 years;
- Requiring a session of professional oral hygiene—FMPS > 25%;
- At least 80% of the mixed dentition erupted and at least 8 of 12 teeth present in the anterior sextant;
- The exclusion criteria were:
 - Systemic diseases;
 - Fixed orthodontic appliances;
 - Presence of prosthetic elements in the anterior sextant;
 - Tumours and/or oral cavity diseases;
 - Recent chemotherapy or radiation therapy;
 - Allergy to erythritol, chlorhexidine, lactose or fermented milk products;
 - Lack of parental consent or unwillingness to comply with the study protocol.

Verbal and written informed consent was obtained from the guardians of all participants.

2.3 | Calibration Procedure—Single-Examiner Calibration (Test–Retest Procedure)

A calibration procedure was performed to assess the intra-examiner reliability of the image analysis.

2.3.1 | First Session (T0)

The examiner analysed 10 images and calculated the residual plaque area (RPA) according to the predefined standard operating procedure (SOP). Results were recorded in a dedicated dataset (image ID → percentage of residual plaque).

2.3.2 | Wash-Out Period

A wash-out interval of 7–14 days was observed to minimize recall of the initial measurements.

2.3.3 | Second Session (T1)

The same examiner repeated the analysis blinded to the T0 results. Images were presented again in a randomized order.

2.3.4 | Ongoing Calibration (Drift Control)

To prevent measurement drift over time, a small internal ‘gold set’ of five previously analysed images was periodically reassessed in a blinded manner approximately every 25–30 participants. If reliability dropped below the predefined threshold, additional training and recalibration were performed. Intra-examiner reliability for the image-based residual plaque area (RPA) measurements was assessed using a test–retest procedure. Consistency between the two measurement sessions was excellent, with an intraclass correlation coefficient at study set-up (ICC) of 0.94% ($N=10$ pairs, 95% CI: 83%–98%), a final ICC of 93% ($N=25$ pairs, 95% CI 86%–96%), and all the intermediate evaluations ($n=5$ measurements, three sets) had an estimate >80%. These results indicate high

reproducibility of the image analysis procedure. This procedure ensured that the measurement of residual plaque area were consistent and reproducible across all evaluators during the clinical trial.

2.4 | Screening and Interventions

Baseline screening was performed by ES on all the potential patients and included soft and hard tissues assessment and FMPS measured at six sites per tooth (mesio-buccal, buccal, disto-buccal, mesio-lingual, lingual and disto-lingual) using a PCP-UNC 15 periodontal probe.

All selected patients received a PMPR session performed by the same clinician (MM). A lips and cheeks retractor (Optragen Oral Retractor, Ivoclar Vivadent) was used to improve access and visibility. Patients were then randomized using a pre-prepared list and sealed, numbered envelopes into one of four treatment groups.

- Treatment A (AF+PD): application of plaque disclosing agent (Biofilm Discloser, EMS, Nyon, Switzerland), rinsed with water, followed by plaque removal with an air-flowing device (Airflow Prophylaxis Master, EMS, Nyon, Switzerland) using erythritol powder (PLUS powder, EMS, Nyon, Switzerland) (Figure 1A–D);
- Treatment B (AF): plaque removal using air-flowing with erythritol powder, without any plaque disclosure (Figure 2A–C);
- Treatment C (CUP+PD): application of plaque disclosing agent, rinsed with water, followed by plaque removal using rubber cup (Pro-junior soft, Kerr) and polishing paste (Cleanic, Kerr, RDA 27) (Figure 3A–D);
- Treatment D (CUP): plaque removal with a rubber cup and polishing paste, without any plaque disclosure (Figure 4A–C).

A timer was started when the randomization envelope was opened and stopped when the clinician judged that all visible disclosing agent or plaque had been removed. At this stage, a

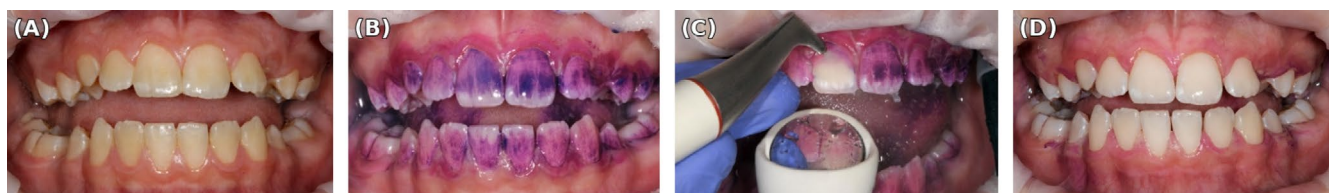


FIGURE 1 | (A–D) Clinical steps of Treatment A (AF+PD): Baseline (A), after-disclosing (B), during AF (C) and post-treatment PD application (D).



FIGURE 2 | (A–C) Clinical steps of Treatment B (AF) (A): Baseline, during AF (B) and post-treatment PD application (C).

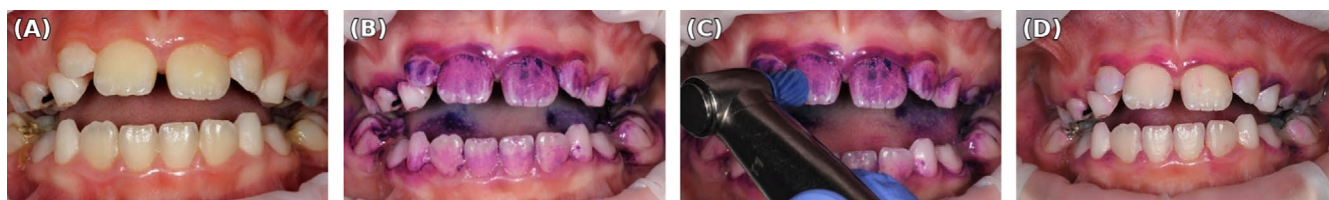


FIGURE 3 | (A–D) Clinical steps of Treatment C (CUP+PD): Baseline (A), after disclosing (B), during plaque removal (C) and post-treatment PD application (D).

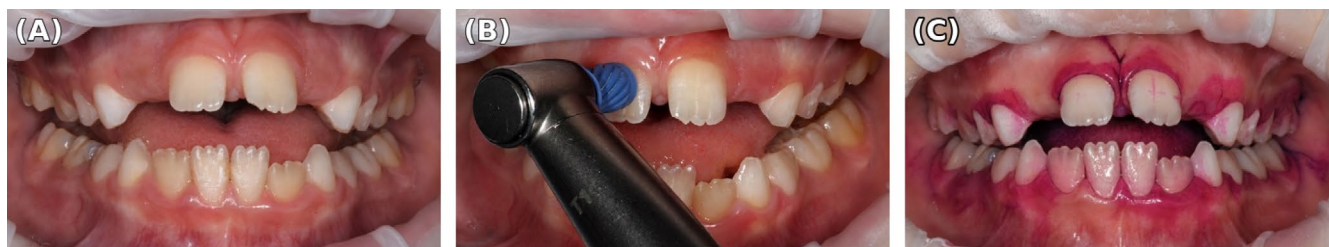


FIGURE 4 | (A–C) Clinical steps of Treatment D (CUP): Baseline (A), during plaque removal (B) and post-treatment PD application (C).

satisfaction questionnaire was administered to both patients and the clinician. The plaque disclosing agent was then reapplied across the full dentition for post-treatment evaluation of residual plaque, including FMPS recording and photographic documentation of the anterior sextants. Images were analysed using ImageJ software. If calculus was detected, it was subsequently removed with a piezoelectric handpiece (Piezon, Airflow Prophylaxis Master, EMS, Nyon, Switzerland) with a Perio Slim tip (PS, EMS, Nyon, Switzerland). The complete study protocol is illustrated in Figure 5.

2.5 | Satisfaction Questionnaire

The child questionnaire was designed to be simple and neutral, avoiding any wording that could influence or guide responses. It included the following questions:

1. Did you feel any discomfort? (Rate from 1 to 10)
2. Do your teeth feel smooth? (Rate from 1 to 10)
3. Would you undergo this treatment again in the future? (Yes/No)
4. Would you recommend this treatment to a friend? (Yes/No)

A separate satisfaction questionnaire was administered to the clinician. Responses were recorded on a 0–10 scale and included the following questions:

1. How would you rate the child's compliance?
6. How would you rate the ergonomics of the treatment technique?
7. How would you rate the performance of the treatment technique?
8. How would you rate your fatigue at the end of the treatment?
9. How easy was it to provide the treatment?

2.6 | Software Image Analysis

Standardized extraoral photographs were taken by ES using a Nikon D90 camera with an AF-S VR Micro-Nikkor 105 mm f/2.8G IF-ED lens, set at a fixed distance of 40 cm, f/36 aperture, and 1/160 s exposure. Lighting was provided by a Metz Mecablitz 15 MS-1 Digital Ring Flash at 1/8 power.

Photographic analysis was performed by MD using ImageJ software. MD was the only blinded outcome assessor, as photographic analysis was performed on anonymized and coded images, preventing identification of the treatment allocation during image evaluation. RPA on anterior vestibular sextants was calculated as a percentage of the total tooth surface. The area of interest was manually selected (vestibular sextants II and V), with particular attention to interproximal spaces and the contour of the gingival margin. Using the Adjust-Colour Threshold command and adjusting the brightness, the entire tooth area was highlighted in red and calculated. Using the Adjust-Colour Threshold command and controlling for the hue, the chromatic range corresponding to the plaque disclosing colour was selected (value range 175–220), allowing for the identification of the RPA. The colour threshold range between 175 and 200 was selected because it corresponds to the chromatic variation of the plaque-disclosing agent used (Mira-2 Ton), which produces staining ranging from pink to deep violet. After application of the disclosing agent, plaque covered areas consistently exhibited colour values within this range and were clearly distinguishable from the surrounding tooth surface. This marked chromatic contrast allowed for selective and reproducible identification of the areas of interest using a pre-defined threshold. With regard to methodological reliability, all operators followed a standardized protocol for region of interest (ROI) selection, based exclusively on the colour difference between the tooth surface and the plaque-stained areas. The clear visual distinction between unstained dental surfaces and pigmented regions minimized subjectivity in manual ROI selection and contributed to consistency among examiners [14, 29].

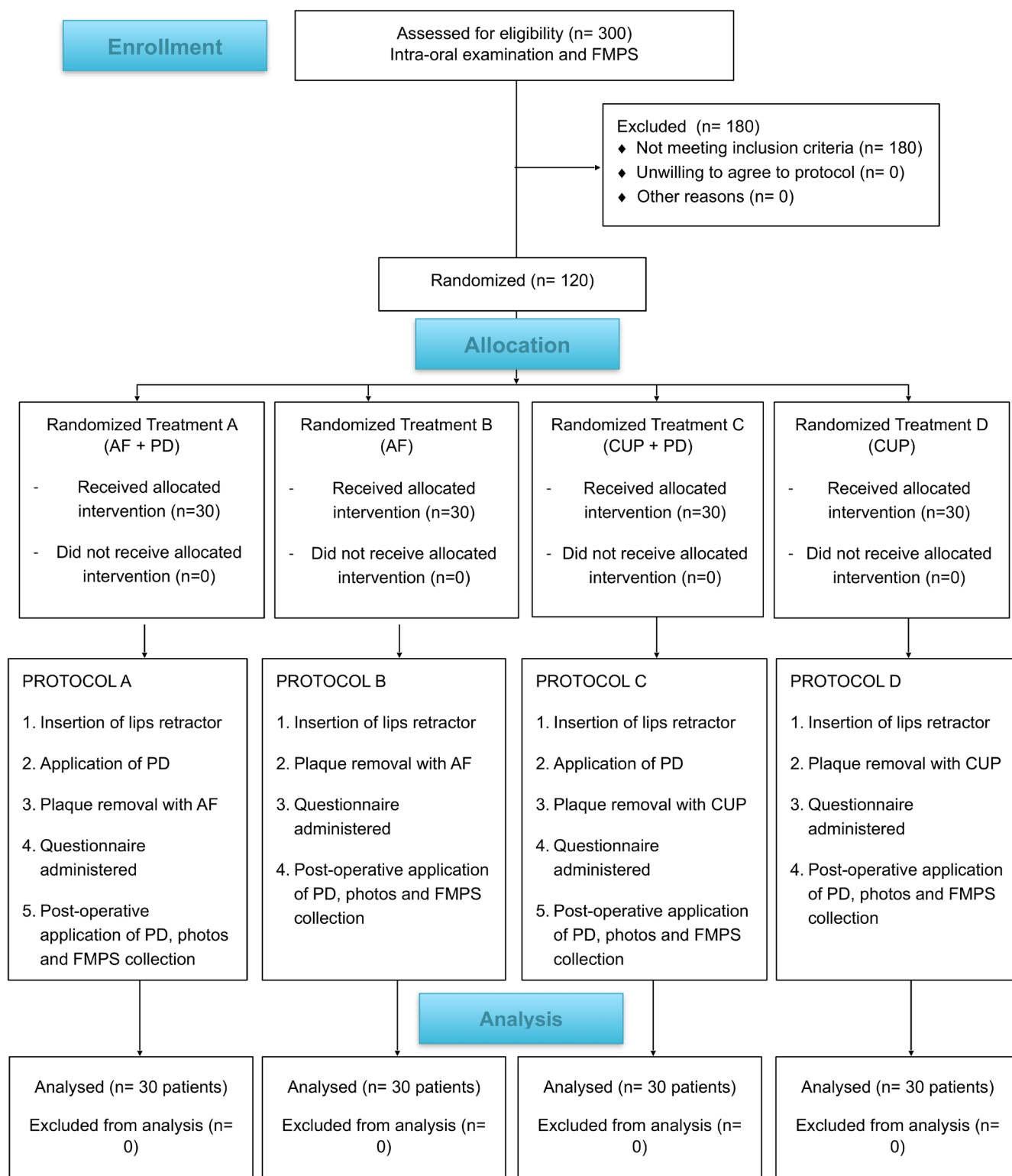


FIGURE 5 | Modified CONSORT (2010) flow-chart illustrating the study protocol and the treatment protocols. AF, airflow; CUP, rubber cup; FMPS, full mouth plaque score; PD, plaque disclosing.

2.7 | Study Outcomes

Primary outcome was to compare post-treatment RPA on anterior vestibular sextants between groups, calculated with photographic

analysis through ImageJ Software. Secondary outcomes were the FMPS recorded as a dichotomous parameter (plaque presence: yes/no), treatment time and treatment feedback of both patients and clinician.

2.8 | Statistical Analysis

Data was described using standard summary statistics such as mean and standard deviations for quantitative variables, absolute counts and proportions for categorical variables. The baseline characteristics were compared among groups using a Kruskal-Wallis non-parametric test for quantitative variables, and a Chi-squared test for qualitative variables. The primary outcome was RPA. RPA, expressed as proportion (0–1) was modelled using a beta-regression model. Results were expressed as estimates and relative 95% confidence intervals. A significant level of 5% was used for all the comparisons and all analysis were performed using R (version 4.2.1). The calibration was performed on the first 10 repeated measurements and then repeated as described above. To evaluate the test–retest performance, we adopted an intraclass correlation coefficient (ICC) estimated using a two-way, single measurement, mixed-effects model. Results are reported as estimate and 95% CI.

2.9 | Sample Size Determination

Sample size was estimated via Monte Carlo simulation (B = 1000 runs). We assumed a beta regression model for RPA with technique (AF, CUP) and PD (No, Yes) as main factors, and their interaction. The parameter of interest is the interaction, that is, if applying the PD is giving better results depending on the main technique used. Using data from a previous study [29] on RPA we estimated the phi parameter for a beta distribution ($\phi = 55$) and assumed a baseline RPA (no PD in either technique) of 10%, with a reduction to 2.9% and 1.5% respectively for AF with or without PD. Through simulation we evaluated the sample size needed to achieve a power of at least 80% for the test on interaction term assuming a 5% significance level. A sample size of 30 patients in each of the four group ($N = 120$ overall) achieved a 83% power.

2.10 | Blinding and Randomization

To minimize bias during image analysis, a predefined workflow for image acquisition, processing, and analysis was implemented.

ES performed participant screening, post-treatment clinical evaluation, and standardized photographic documentation, while MM conducted all clinical treatments. Following image acquisition, photographs were anonymized and assigned coded identifiers independent of treatment allocation. MD subsequently performed the quantitative image analysis using ImageJ software and was blinded to treatment allocation throughout the image assessment.

In addition, statistical analyses were performed by a statistician who was kept blinded to treatment allocation through the use of anonymized treatment codes corresponding to all possible combinations of treatment (A-b) and plaque disclosing usage (B-b). This procedure represents a standard methodological approach to minimize analytical bias and should not be interpreted as defining the level of blinding of the clinical trial (e.g., single- or double-blind), which refers to the blinding of participants, clinicians and/or outcome assessors.

Randomization was achieved using a computer-generated randomization table based on a permuted block randomization algorithm, which allocated each participant to one of the four treatment groups.

3 | Results

Out of 300 children screened, 180 were excluded, primarily due to not meeting the requirement of $\geq 80\%$ dentition present. A total of 120 patients (52 females, 68 males) were enrolled and provided consent to participate in the study. Thirty patients were randomly assigned to each treatment groups and all received the intended intervention (Figure 2). No dropouts or post-randomization exclusions occurred. Patient enrolment started on the 06/03/2023 and finished on the 22/07/2024. At baseline, demographic characteristics and FMPS were comparable across groups. (Table 1).

The lowest RPA was observed in Treatment A (AF + PD), with a median value of 0.19% (CI: 0.12–0.29), whereas the highest RPA

TABLE 1 | Demographic characteristics of the study population.

Treatment group	Overall	A (AF + PD)	B (AF)	C (CUP + PD)	D (CUP)	<i>p</i>
Number of patients	120	30	30	30	30	—
Gender						
Females (%)	52 (43%)	12 (40%)	17 (57%)	12 (40%)	11 (37%)	0.4
Males (%)	68 (57%)	18 (60%)	13 (43%)	18 (60%)	19 (63%)	
Mean age						
Years (SD)	9.65 (1.85)	9.87 (1.89)	9.83 (1.78)	9.80 (1.90)	9.10 (1.83)	0.4
FMPS (%)						
FMPS % (SD)	68% (28)	67% (30)	72% (24)	69% (30)	65% (30)	0.8
Mean number of teeth						
Anterior teeth (SD)	11.58 (0.75)	11.73 (0.45)	11.60 (0.77)	11.40 (0.97)	11.60 (0.72)	0.6
Posterior teeth (SD)	12.06 (2.51)	12.20 (2.95)	12.23 (2.84)	11.80 (2.34)	12.00 (1.88)	0.8

Abbreviations: AF, air-flowing; CUP, rubber cup; FMPS, full mouth plaque score; PD, plaque disclosing agents; SD, standard deviation.

was recorded in Treatment D (CUP without PD), at 2.17% (CI: 1.41–3.33) (Table 2).

When treatment groups were compared, Treatment A (AF+PD) showed a significantly lower RPA than all other groups. Treatment B (AF) achieved significantly lower RPA than Treatment D (CUP) and produced results comparable to Treatment C (CUP+PD). Overall, the use of PD was associated with significantly lower RPA, irrespective of the instrument employed (Table 3).

A similar trend was observed for FMPS. Treatment A (AF+PD) achieved the lowest plaque score (6.03% [CI: 3.08–8.97]), whereas Treatment D (CUP) showed the highest (21.78% [CI: 18.83–24.73]) (Table 4). Treatments B (AF) and C (CUP+PD) yielded comparable results.

Statistical analysis confirmed that Treatment A (AF+PD) was significantly superior to all other groups, while Treatments

B (AF) and C (CUP+PD) showed comparable outcomes (Table 5).

The recorded treatment times were comparable among Treatments A, B, and C (around 12 min on average), whereas Treatment D (CUP) required significantly less time than all other groups (6.88 [4.42–9.34]) (Tables 6 and 7).

Regarding patient perception, reported discomfort was consistently low across all treatment modalities, with Treatment A (AF+PD) showing slightly higher ratings, as 97% of patients reported no discomfort. The sensation of smoothness was also rated highly for treatments involving AF (90% for treatment A and 87% for treatment B), whereas treatments with rubber cups received lower ratings (57% for treatment C and 53% for treatment D). Most patients indicated they would undergo the treatment again and would recommend it to a friend, particularly when AF was involved. (Table 8).

TABLE 2 | Percentage of Residual Plaque Area (%RPA) post treatment for each group.

Group	Mean (CI)
A (AF+PD)	0.19% (0.12–0.29)
B (AF)	0.64% (0.41–0.98)
C (CUP+PD)	0.96% (0.62–1.47)
D (CUP)	2.17% (1.41–3.33)

Abbreviations: AF, air-flowing; CI, confidence interval; CUP, rubber cup; PD, plaque disclosing agents.

TABLE 3 | Comparison between treatment groups in terms of ratio of post-treatment RPA (%).

Contrast	Ratio (CI)	<i>p</i>
B/A	3.34 (1.82–6.13)	< 0.01
C/A	5.01 (2.73–9.20)	< 0.01
C/B	1.50 (0.82–2.76)	0.19
D/A	11.35 (6.17–20.85)	< 0.01
D/B	3.40 (1.85–6.24)	< 0.01
D/C	2.26 (1.23–4.16)	< 0.01

Note: Bold values indicate statistically significant results. Abbreviation: CI, confidence interval.

TABLE 4 | Mean Full Mouth Plaque Score (FMPS %) post treatment for each group.

Group	Mean (CI)
A (AF+PD)	6.03 (3.08–8.97)
B (AF)	14.70 (11.75–17.65)
C (CUP+PD)	13.18 (10.23–16.12)
D (CUP)	21.78 (18.83–24.73)

Abbreviations: AF, air-flowing; CI, confidence interval; CUP, rubber cup; PD, plaque disclosing agents.

TABLE 5 | Comparison between treatment groups in terms of post-treatment FMPS (%).

Contrast	Ratio (CI)	<i>p</i>
B/A	8.67 (4.50–12.85)	< 0.01
C/A	7.15 (2.99–11.32)	< 0.01
C/B	–1.52 ((–5.69)–2.65)	0.47
D/A	15.76 (11.59–19.52)	< 0.01
D/B	7.08 (2.90–11.27)	< 0.01
D/C	8.61 (4.44–12.78)	< 0.01

Note: Bold values indicate statistically significant results. Abbreviation: CI, confidence interval.

TABLE 6 | Average treatment time in minutes per each group.

Group	Mean (CI)
A (AF+PD)	12.01 (9.23–14.80)
B (AF)	12.48 (10.02–14.93)
C (CUP+PD)	12.92 (10.46–15.38)
D (CUP)	6.88 (4.42–9.34)

Abbreviations: AF, air-flowing; CI, confidence interval; CUP, rubber cup; PD, plaque disclosing agents.

TABLE 7 | Comparison between groups in terms of treatment time.

Contrast	Ratio (CI)	<i>p</i>
B–A	0.46 ((–3.25)–4.18)	0.80
C–A	0.90 ((–2.81)–4.62)	0.62
C–B	0.44 ((–3.03)–3.92)	0.80
D–A	–5.13 ((–8.85)–(–1.42))	< 0.01
D–B	–5.60 ((–9.07)–(–2.12))	< 0.01
D–C	–6.04 ((–9.52)–(–2.56))	< 0.01

Note: Bold values indicate statistically significant results. Abbreviation: CI, confidence interval.

TABLE 8 | Patient feedback questionnaire.

	A (AF + PD)	B (AF)	C (CUP + PD)	D (CUP)
Have you felt any discomfort? (Answer a number from 1–10)				
No (1–3)	97%	73%	70%	72%
A little bit (4–7)	3.3%	17%	17%	17%
Yes (8–10)	0%	10%	13%	6.7%
Do your teeth feel smooth? (Answer a number from 1–10)				
No (1–3)	3.3%	0%	0%	6.7%
Enough (4–7)	6.7%	13%	43%	40%
Yes (8–10)	90%	87%	57%	53%
Would you do that again in the future? (Yes/No)				
No	3.3%	10%	13%	17%
Yes	97%	90%	87%	83%
Would you recommend it to one of your friends? (Yes/No)				
No	3.3%	10%	10%	27%
Yes	97%	90%	90%	73%

Abbreviations: AF, air-flowing; CUP, rubber cup; PD, plaque disclosing agents.

Clinician perception was overall positive across all treatment modalities. Children's compliance, ease of treatment provision, and ergonomics were rated similarly across groups. However, the clinician rated the performance of Treatment A (AF + PD) highest and reported less fatigue after treatments involving AF (Treatments A and B) compared with CUP. (Table 9).

4 | Discussion

Traditional PMPR in children typically involves the use of a rotating rubber cup paired with polishing paste to simultaneously remove dental plaque and polish tooth surfaces. However, this method can be challenging due to limited access to all dental surfaces, reduced visibility, and variable cooperation among paediatric patients. The present randomized controlled trial therefore compared the efficacy of four different PMPR protocols and collected feedback from both patients and the clinician, with a particular focus on two adjunctive tools: air-flowing with a low-abrasiveness powder and plaque disclosing agents. Our findings demonstrate that the combined use of airflow and plaque disclosing significantly improves plaque removal in children, leading to lower residual plaque levels as measured by both RPA and FMPS.

Airflow debridement—formerly known as air-polishing [17, 18]—uses a jet of air, water, and low-abrasiveness powder to disrupt plaque and biofilm. This technique has been validated in adults as a minimally invasive approach for periodontal patients [16, 23, 33, 34], patients with gingivitis [14, 15] and dental implants maintenance [17]. Promising results have also been reported in orthodontic patients, where airflow facilitates debridement around brackets and wires [35, 36]. However, evidence in paediatric populations remains limited, and to our knowledge, this is the first trial directly comparing traditional rubber cup polishing

TABLE 9 | Clinician feedback questionnaire.

A (AF + PD)	B (AF)	C (CUP + PD)	D (CUP)	p
<i>How would you rate the child's compliance? (Answer a number from 1–10)</i>				
9.27	9.10	8.60	8.63	0.10
<i>How would you rate the ergonomics of the treatment technique? (Answer a number from 1–10)</i>				
9.13	8.83	8.53	8.43	0.030
<i>How would you rate the performance of the treatment technique? (Answer a number from 1–10)</i>				
9.27	8.53	8.33	8.30	<0.001
<i>How would you rate your fatigue at the end of the treatment? (Answer a number from 1–10)</i>				
1.33	1.73	2.03	2.40	<0.001
<i>How easy was to provide the treatment? (Answer a number from 1–10)</i>				
9.60	9.40	9.53	8.77	0.003

Note: No adverse events (e.g., allergic reaction, pain, swelling, medical episodes etc.) were observed during the study. Bold values indicate statistically significant results.

Abbreviations: AF, air-flowing; CUP, rubber cup; PD, plaque disclosing agents.

with air-flowing in children. Our results show that airflow produced lower residual plaque scores than rubber cups, regardless of whether plaque disclosing was used, confirming its superior efficacy in plaque removal. These findings are supported by two complementary outcome measures: Residual Plaque Area (RPA), which demonstrated significantly lower residual plaque on the

anterior vestibular sextants, and Full Mouth Plaque Score (FMPS), recorded on the entire dentition, which consistently showed lower whole-mouth plaque levels following treatment ($p < 0.01$; Tables 2–5). This may reflect the ability of the airflow jet to reach a broader surface area and penetrate interproximal, posterior, and lingual sites more effectively than rubber cups, which are difficult to manoeuvre in these areas [30, 37].

Interestingly, air-flowing without plaque disclosing (treatment B) performed comparably to rubber cup polishing with disclosing (treatment C). This suggests that not only air-flowing but also plaque visualization plays a critical role in PMPR quality (Tables 2 and 4).

The positive outcomes with airflow align with Wolgin et al. [38], who reported lower plaque scores in adults compared with rubber cups. On the other hand, Mensi et al. [29] observed no significant reduction in RPA in the anterior sextants of adults, which may be explained by the inherently easier access to anterior teeth in adults, regardless of the technique used.

Since dental plaque and biofilm are difficult to visualize, methods that enhance detection are expected to improve removal. Our results confirm that plaque disclosing enhances PMPR, regardless of the instrument used. For instance, airflow with plaque disclosing (treatment A) outperformed airflow alone (treatment B), particularly in FMPS outcomes that assess posterior and lingual sites where visibility is most limited. Similar benefits were observed with rubber cups: plaque disclosing halved residual plaque scores compared to rubber cups alone.

These findings are consistent with de Alencar et al. [30], who demonstrated improved plaque removal with disclosing in children, and with our previous adult data showing that disclosing enhances airflow performance, especially in interproximal and lingual areas [29] where visibility is reduced or obtained indirectly by a mirror. Collectively, these results confirm the value of plaque disclosing as a simple yet powerful adjunct to PMPR.

Treatment time and patient feedback were secondary outcomes, but highly relevant in paediatric dentistry. Anxiety and lack of cooperation are common obstacles to care in children [13, 39]. Although plaque removal is not generally perceived as painful [39], positive experiences during preventive procedures may increase adherence, reduce the need for invasive restorative treatments and support long-term preventive behaviours [12, 39, 40]. In our trial, the shortest procedure was rubber cup polishing without disclosing (treatment D), but this came at the cost of significantly inferior plaque removal. Conversely, disclosing-based protocols required slightly longer sessions, yet yielded substantially superior outcomes. Notably, treatment times for airflow with and without disclosing were similar, but the improved plaque removal with disclosing suggests that visualization may enable a more targeted and efficient debridement process, consistent with findings by de Alencar et al. [30].

Interestingly, treatment B (AF) required a similar overall time as the plaque disclosing-guided protocols (treatment A and C). Firstly, one must keep in mind that the recorded time for treatment A (AF + PD) and C (CUP + PD) also includes the few minutes utilized for the application of the plaque disclosing agent.

This suggests that, when comparing treatments, A and B, the actual debridement phase was likely shorter for treatment A, even though the total recorded time was similar. Plaque disclosing may allow a more precise and targeted application of airflow, reducing unnecessary instrumentation. This aligns with de Alencar et al. [30], who showed that plaque disclosing decreased debridement time despite adding the staining step. Another possible explanation is that, in the absence of plaque disclosing in treatment B, the clinician may have spent more time with airflow to ensure coverage of all tooth surfaces, carefully applying the recommended slow, overlapping back-and-forth motion throughout the arch.

Patient-reported outcomes reinforce the clinical advantages of airflow with plaque disclosing. Treatment A (AF + PD) achieved the highest comfort ratings, with nearly all children reporting no discomfort compared to lower rates in the other groups. The engaging nature of disclosing—allowing children to see coloured plaque—may have reduced anxiety and enhanced cooperation. Moreover, the targeted nature of airflow under visual guidance likely minimized unnecessary repetition and discomfort. While concerns have been raised about water output during airflow, which may provoke a choking sensation in some children [13], this was not reported in our study, likely due to the improved ergonomics of modern devices.

Finally, a higher proportion of patients reported a pleasant sensation of smoothness after treatments involving air-flowing compared with rubber cup polishing (Table 8). These findings reinforce the recent shift towards minimally invasive interventions and the abandonment of traditional ‘tooth polishing’. Evidence shows that even soft rubber cups and low-abrasive pastes can cause microscopic enamel damage, leading to unnecessary loss of healthy tooth structure without improving surface smoothness [41]. Although stain assessment was not part of the present study, it is interesting to mention that Okmus et al. [42] demonstrated in vitro that rubber cup polishing in primary dentition may actually increase subsequent discoloration, likely due to alterations of the enamel surface. Overall, the questionnaire results indicate high patient satisfaction, compliance, and willingness to undergo preventive PMPR in the future, with a slight preference for AF-based protocols.

Clinician feedback also favoured airflow-based treatments, which were perceived as less fatiguing and ergonomically easier to perform compared with rubber cups. Airflow handpieces are lighter and easier to handle than contra-angle attachments and disclosing provided valuable guidance. Despite shorter times, rubber cups were rated as less satisfactory, reflecting their inherent limitations in access and efficacy. These observations are consistent with previous studies in adults, where airflow was associated with higher patient satisfaction, reduced discomfort, and lower treatment times [14, 15].

In two previous studies in adults conducted by our group [14, 15], airflow debridement was associated with significantly higher patient-perceived quality and lower discomfort, consistent with the present findings. In those studies, reduced treatment time was also noted. This was largely attributed to the decreased use of ultrasonic scaling when air-flowing was applied. In paediatric patients, however, the need for calculus removal is minimal or

absent; therefore, the present investigation focused exclusively on the plaque removal component of the PMPR session.

No side effects were recorded at any point during the study. It is important to note that the clinician was well trained in the provision of airflow debridement, and a very low abrasiveness powered was used (erythritol). When performed with the appropriate technique and powder, air-flowing is considered a minimally invasive and gentle PMPR method, safe for natural dentition, soft tissues, and restorative materials [19, 20, 41]. The present study has some limitations. First, the RPA assessment did not include the posterior sextants, which could potentially be evaluated in future studies using standardized extraoral photographs with mirrors. Second, all treatments were provided by the same experienced clinician. Although this approach minimized operator-related variability and improved the internal consistency of the study, it may limit the external validity of the findings. In addition, clinician-reported outcomes, such as treatment ergonomics, performance, fatigue and ease of treatment, are inherently subjective and may have been influenced by the operator's experience and perception. These outcomes were included as secondary exploratory measures, whereas the primary outcome (RPA) and the clinical outcome (FMPS) were objective quantitative measures. Future multicentre studies involving multiple clinicians with different levels of experience are therefore warranted to confirm the reproducibility and generalizability of the present findings. Finally, longitudinal observation over repeated PMPR sessions would allow confirmation of the effectiveness and the consistency of these approaches, as well as their long-term impact on patient acceptance and preventive care outcomes.

An additional limitation of the study is related to the method used to detect residual plaque, which was based exclusively on the evaluation of vestibular photographs due to obvious technical reasons. This may have led to differences in the results if occlusal and lingual sites had also been considered; however, as this was a clinical experimental study, it was not possible to adopt different methodologies with the instruments available.

The availability of intraoral scanners equipped with artificial intelligence applications, capable of detecting and highlighting dental plaque before and after the intervention without the need for disclosing agents, photographic documentation, or the transfer of images into dedicated software, could facilitate the repetition of the workflow while helping to bypass potential technical biases.

5 | Conclusions

In paediatric patients, the combination of plaque disclosing and airflow debridement resulted in significantly lower residual plaque levels on the assessed anterior vestibular sextants compared with traditional rubber-cup polishing. In addition, the protocol achieved lower Full Mouth Plaque Scores (FMPS), which were recorded on the entire dentition, and was associated with high levels of patient comfort and clinician satisfaction.

Although the primary outcome was limited to the anterior vestibular sextants because of the standardized photographic methodology adopted for quantitative image analysis, the consistent

improvement observed in the whole-mouth FMPS supports the potential clinical benefit of plaque disclosure-guided airflow debridement as an adjunct to paediatric preventive protocols.

Nevertheless, further studies using validated methods capable of assessing residual plaque on all tooth surfaces are needed to confirm these findings and to determine the effectiveness of this approach for whole-mouth plaque removal.

6 | Clinical Relevance

6.1 | Scientific Rationale for Study

To compare four different methods of professional supragingival biofilm removal in paediatric patients: air-flow with disclosing agent, air-flow without disclosing agent, rubber cup with disclosing agent and rubber cup without disclosing agent have been testing.

6.2 | Principal Findings

The paediatric patients are enthusiastic to play with disclosing agent and they like the comfort of air-flow treatment.

6.3 | Practical Implications

Air-flowing and plaque disclosing agents may represent a valid solution to professional oral hygiene in paediatric patients. The tested protocol is suitable for the maintenance and results in higher comfort.

Author Contributions

M.M. and E.B. conceived the ideas. M.M. clinician. S.E. collected the data and photographs. D.M. validation of software analysis. M.S. and S.A. wrote the article, G.G. and E.M. designed the tables and figures. C.S. analysed the data.

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Conflicts of Interest

M.M. reports Personal fees from EMS outside the submitted work. The remaining authors declare no conflicts of interest.

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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