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ORIGINAL ARTICLE

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Clinical evaluation of air polishing with erythritol powder followed by ultrasonic calculus removal versus conventional ultrasonic debridement and rubber cup polishing for the treatment of gingivitis: A split-mouth randomized controlled clinical trial

Magda Mensi[1,2] | Eleonora Scotti[1,2] | Annamaria Sordillo[1] | Matteo Dalè[1] | Stefano Calza[3]

[1]Section of Periodontics, School of Dentistry, Department of Surgical Specialties, Radiological Science and Public Health, University of Brescia, Brescia, Italy

[2]U.O.C. Odontostomatologia – ASST degli Spedali Civili di Brescia, Brescia, Italy

[3]Department of Molecular and Translational Medicine, University of Brescia, Brescia, Italy

Correspondence
Magda Mensi, Section of Periodontics, School of Dentistry, Department of Surgical Specialties, Radiological Science and Public Health, University of Brescia, P.le Spedali Civili 1, 25123 Brescia, Italy.
Email: magda.mensi@unibs.it

Abstract

Objectives: To evaluate the clinical efficacy in the short-term resolution of gingivitis of a novel protocol involving full-mouth erythritol powder air polishing followed by ultrasonic calculus removal.

Methods: Forty-one healthy patients completed the study. Following a split-mouth design, quadrants 1–4 and 2–3 were randomly allocated to receive air polishing followed by ultrasonic calculus removal (A+US) or traditional full-mouth ultrasonic debridement followed by polishing with a rubber cup and prophylactic paste (US+P). Bleeding on probing (BoP) and plaque index (PI) were collected at baseline and 2 and 4 weeks. Moreover, the residual plaque area (RPA), treatment time and patient comfort/satisfaction were evaluated at the end of the treatment.

Results: Both treatments showed a significant reduction in BoP and PI. At 4 weeks, A+US seems to reach a statistically significant lower BoP (8.7% [6.9; 10.9] vs. 11.6%[9.3; 14.4], $p < 0.0001$) and PI (10.7% [8.9; 13.0] vs. 12.3% [10.2; 14.9], $p = 0.033$). Moreover, A+US treatment time lasted on average 9.2% less than US+P ($p < 0.0001$) and was the preferred treatment for a significantly higher number of patients (73.2% vs. 17.1%, $p = 0.0001$).

Conclusion: The A+US protocol is suitable for the short-term resolution of plaque-induced gingivitis.

KEYWORDS
air polishing, dental biofilm, gingivitis, oral hygiene, plaque disclosing

1 | INTRODUCTION

Gingivitis represents the first inflammatory response of the gingival tissues towards biofilm accumulation.[1] It is characterized by redness, oedema and bleeding on probing (BoP) without evidence of attachment loss.[2] According to the new Periodontal Classification, localized gingivitis is characterized by a BoP score between 10% and 30%, while BoP > 30% defines generalized gingivitis.[2]

Mechanical biofilm removal is the key treatment for gingivitis. Professional supragingival and submarginal plaque and calculus

removal, accompanied by home oral hygiene instructions, can resolve gingivitis in 7–14 days.[1,3]

Traditional biofilm removal protocols involve manual and mechanical instruments, followed by polishing with a rubber cup and abrasive paste, with or without air polishing with sodium bicarbonate powder to remove extrinsic stains. While this treatment is adequate for plaque and calculus removal, it might come with side effects. Ultrasonic instrumentation for dentine and cementum removal,[4] can damage the enamel increasing its surface roughness[5] and break the epithelial attachment causing recession with subsequent hypersensitivity.[6] Abrasive pastes are also shown to damage the enamel architecture.[7]

Air polishing with new low-abrasiveness powders (glycine and erythritol) can be a suitable option for both supra- and subgingival plaque removal while preserving the treated surface,[7-9] providing higher comfort for the patient and saving time.[10]

When it comes to removing biofilm efficiently, plaque disclosing agents can assist both the clinician and the patients. Visible biofilm can help educate and motivate patients,[11] and guide the professional treatment to achieve a more thorough plaque removal, especially in areas of difficult access.[12] For research purposes, plaque disclosing can also be used for photography software analysis and computer plaque quantification,[13] overcoming the limitations of classic traditional indices, such as inter-examiner variability.[14]

Recently, a new protocol for professional prophylaxis has been introduced, involving a plaque disclosing agent and air polishing with erythritol powder for biofilm removal, followed by site-specific ultrasonic instrumentation for calculus removal. This protocol is known by the commercial name of Guided Biofilm Therapy® (GBT).

The aim of the present split-mouth randomized controlled study was to evaluate the efficacy of air polishing followed by ultrasonic calculus removal (A+US) for the resolution of gingivitis in terms of reduction in bleeding on probing (BoP) at 2 and 4 weeks, compared with conventional full-mouth ultrasonic debridement followed by rubber cup with abrasive paste (US+P). Secondary aims were the evaluation of Residual Plaque Areas (RPA), treatment time and patient comfort/satisfaction, and plaque index change at 2 and 4 weeks.

2 | STUDY POPULATION AND METHODOLOGY

2.1 | Study design and population

The present study was a double-blinded, split-mouth randomized controlled clinical trial, approved by the Ethics Committee of ASST—Spedali Civili di Brescia (Italy) with protocol number 2637, and conducted in accordance with the Helsinki Declaration. Patients were selected from the population afferent to the Dental School 'Clinica Odontoiatrica Lidia Verza', University of Brescia, Department of Radiological Science and Public Health, within the ASST Spedali Civili di Brescia, Department of Odontostomatology (Brescia, Italy).

Inclusion criteria were as follows:

- Presence of gingivitis (BoP > 25%);
- Presence of at least 5 teeth per quadrant;
- Systemically healthy;
- Age between 20 and 40 years.

Exclusion criteria were as follows:

- Presence of periodontal disease, defined as >3 mm of clinical attachment loss at any site;
- Presence of fixed retainers, orthodontic appliances or complex prosthetic restorations;
- Presence of crowding;
- Pregnant or lactating;
- Allergy to chlorhexidine or erythritol;
- Smoking >10 cigarettes per day;
- Unwillingness to undergo the proposed treatment and recalls;

All participants signed written informed consent before the beginning of the study.

2.2 | Outcomes

The study's primary endpoint was the change in the percentage of sites showing BoP at 2 weeks (T1) and 4 weeks (T2). Secondary outcomes were post-treatment residual plaque area (RPA) in sextants 2 and 6 calculated via computer software analysis of clinical photographs, treatment time, patient's perception of comfort and treatment preference collected through a questionnaire, and change in PI at T1 and T2. GI was collected for completeness of periodontal charting, but was not a primary nor secondary outcome.

2.3 | Intervention

The same trained dentist blinded to the treatment (M.D.) performed the clinical examination, and collected the periodontal parameters and the clinical photographs. The treatments were provided by the same trained dentist (E.S.)

Age, gender and smoking status were collected at baseline, along with a complete periodontal charting including 6-point pocket probing depth (PPD), clinical attachment level (CAL), plaque index (PI) according to a modified O'Leary index (O'Leary et al. 1972)[15] measured on 6 surfaces per tooth (distobuccal, buccal, mesiobuccal, distolingual, lingual and mesiolingual), bleeding on probing (BoP) and gingival index (GI) according to Loe & Silness.[16]

After a pre-treatment 60-seconds rinse with chlorhexidine 0.12% (Curasept, Curaden Healthcare Srl, Saronno, Italy) and placement of a lip and cheek retractor (OptraGate, Ivoclar Vivadent), a plaque disclosing agent (MIRA-2-TON® 60-mL bottle, HAGER & WERKEN) was applied with a micro-brush to cover the entire tooth surface,

and thoroughly rinsed with water. At this point, quadrants 1–4 and 2–3 were randomly allocated to A+US or US+P treatment via randomization list and numbered opaque envelopes. All the quadrants were treated in the same session, starting from 1 to 4.

The quadrants allocated to US+P treatment underwent the following steps:

- Full-mouth ultrasonic piezoelectric debridement (Air-Flow Master Piezon®, EMS) with a slim tip (PS® Instrument, EMS);
- Plaque removal and polishing with rubber cup (Pro Cup Soft Light Blue® Kerr) and prophylaxis paste with RDA = 27 (Cleanic®, Kerr).

The quadrants allocated to A+US underwent the following steps:

- Supragingival and submarginal air polishing (Air-Flow Master Piezon®, EMS) with erythritol + chlorhexidine powder (PLUS®, EMS);
- Site-specific removal of calculus with ultrasonic piezoelectric scaler (Air-Flow Master Piezon®, EMS) and a slim tip (PS® Instrument, EMS).

To safely control aerosol, double suction with both slow-speed and high-speed inserts was applied through a 2-hand technique with an assistant. Treatment time was recorded starting from the opening of the envelope and ending when the clinician was satisfied by the result.

The plaque disclosing agent was reapplied at the end of the treatment, and photographs of the second and fifth sextants were taken. A white-colour calibration target was used in conjunction with mirrors to collect buccal, lingual and palatal photographs. Additional photographs of the remaining sextants were taken for clinical record. An extra-oral camera was used (Nikon D90 with AF-S VR Micro-Nikkor 105 mm f/2.8G IF-ED) with standardized camera settings (focus distance 40 cm to subject, f/36, 1/160s) and flash settings (Metz Mecablitz 15 MS-1 Digital Flash Annular, 1/8 flash power for the buccal shots and 1/4 flash power for the lingual and palatal).

After the removal of the residual plaque disclosing according to the allocated treatment, Oral Hygiene Instructions (OHI) were provided. All the patients were recommended a manual soft brush (CURAPROX CS 5460, Postfach), interdental floss (CURAPROX PTFE Dental Tape, Postfach) and regular sodium fluoride 0.24% w/w toothpaste (GUM® Hydral, Sunstar Gums, RDA < 40).

A questionnaire was administered at the end of the session, investigating the comfort/discomfort level of the 2 treatments, the post-treatment feeling of cleanliness and the patient's preference between the two modalities.

Patients were recalled at 2 and 4 weeks. OHI were provided, and BoP and PI were collected.

The complete study protocol is shown in Figure 1.

2.4 | Software image analysis

Adobe Photoshop (Adobe Photoshop CS.5, Adobe Systems Inc.) was used on a drawing tablet to elaborate the clinical pictures. Per each image, the clinical crowns were selected from incisal to the gingival margin, excluding soft tissues and background. The cropped sections were then transferred as a TIFF file to ImageJ (National Institutes of Health) for software area analysis. The sections were converted to RGB stacks and then to greyscale. Through the colour threshold selection function, the range within the 0–255 greyscale correspondent to the purple/pink colour of the disclosing agent was set. The pixel-based percentage of the disclosing coloured areas was then calculated, representing the residual plaque area (RPA; Figure 2).

2.5 | Sample size

Sample size was estimated for a split-mouth design with a non-inferiority hypothesis setting. Within patient, 36 sites are treated with either procedure (6 teeth, 6 sites for each tooth, on each side). We used two different approaches for sample size estimation. In all setting, we assumed at least a 70% reduction in BOP and a non-inferiority margin of 5%, a power of 80% and a significance level of 5%. First, we modelled the outcome variable as the percentage of sites that stop bleeding on probing after treatment compute sample size assuming asymptotic normality using a paired *t* test procedure. Assuming an average 70% reduction and standard deviation of 12%, a margin of 5% and a zero true difference between treatment, we estimate $N = 38$.

In the second setting, we used a simulation procedure modelling every site change in BOP status as a binomial variate. We therefore simulated a 1-level multilevel structure with both random intercept and slope (treatment effect), that is assuming a varying plaque index and treatment effect across patients. We assumed a true treatment effect of zero across patients, both intercept variance and treatment effect variance were set to 0.5, and intercept-slope correlation was set to −0.6. We simulated $B = 200$ random data sets and estimated power as the proportion of simulations where the margin between the estimated effect is lower than 5%. The simulation procedure led to $N = 41$, which is the selected sample size.

2.6 | Randomization

Patients were randomized by a blinded statistician using a computer-generated randomization list. The random allocation sequence was generated with uninformative labels (A and B) and concealed in sealed opaque envelopes provided by the study adviser. All data analyses were carried out according to a pre-established analysis plan by a biostatistician blinded to group allocation.

2.7 | Statistical analysis

All data analyses were carried out according to a pre-established analysis plan by a biostatistician blinded to group allocation. Due to the split-mouth design of the study, the BoP score was calculated

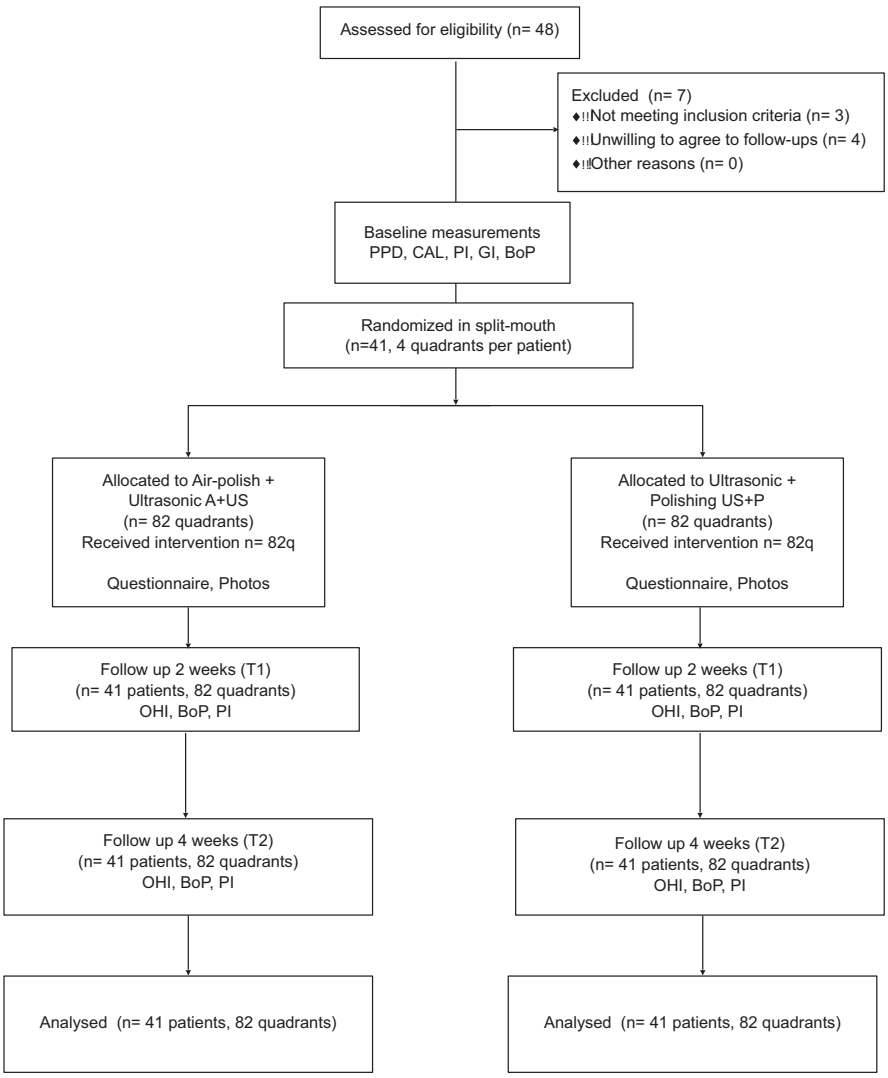

FIGURE 1 Study protocol

as the numbers of BoP-positive sites divided by the total number of sites in the quadrants allocated to each treatment. Comparison of BOP between treatments was performed with two approaches. First, a paired TOST with robust variance estimation was performed on within-subject percentages. Second, we modelled a number of BOP sites using the Poisson regression fitted via generalized estimating equations (GEEs) using the total number of sites as an offset. The same model was adopted for PI. Secondary outcomes were compared assuming superiority hypothesis framework using permutation tests (a non-parametric test procedure) for paired samples. All statistical comparisons were conducted at the 5% level of significance.

3 | RESULTS

Forty-eight patients were assessed for eligibility. 7 patients were excluded for not matching the inclusion criteria (3 showing sites with CAL >3mm and 4 unwilling to agree to the follow-up schedule). Recruitment started on 03/03/2017 and ended on 01/02/2018. A total of 41 patients (21 males and 20 females) were selected, and all of them completed the study. Table 1 shows the demographic characteristics and clinical parameters at baseline. The mean periodontal parameters were reported, grouping the quadrants per treatment group.

Table 2 shows the change in BoP over observation time. Both treatments show a significant reduction in BoP, reaching values below the 25% cut-off used for the present study. At 2 weeks (T1), BoP levels are comparable between A+US (6.1% [4.4%; 8.4%]) and US+P (7.3% [5.2%; 10.2%]), while at 4 weeks, there is a significant increase in BoP for both groups, with A+US maintaining a statistically significant lower number of bleeding sites (11.2% [7.7%; 16.5%] vs 14.8% [10.6%; 20.6%], $p < 0.01$). Figure 3 further clarifies the effect of the two treatments on BoP values by representing the ratio between mean A+US BoP-positive sites and mean US+P BoP-positive sites. Being the ratio below 1, completely including the confidence intervals, A+US resulted in superior BoP reduction.

Table 3 shows the image software analysis results on the post-treatment clinical photographs with plaque disclosing agent. Both treatments were able to eliminate most of the plaque, reaching very low post-treatment plaque levels with no significant intergroup difference: 1.51% [1.2; 1.9] for A+US and 2.96% [2.3; 3.8] for US+P.

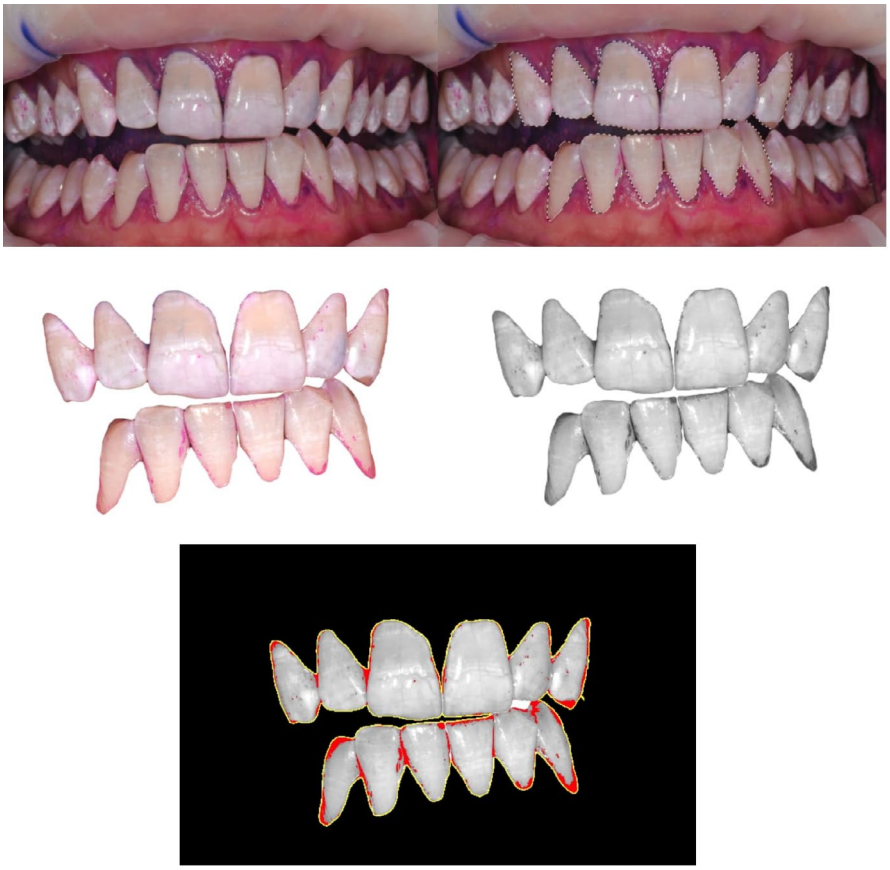

FIGURE 2 Software Image Analysis. The clinical image (A) was uploaded on a drawing tablet, and the clinical crowns were selected. The cropped selections (B) were transferred to ImageJ software, and converted into RGB stacks and then greyscale (C). Through colour threshold function, the grey shades corresponding to the disclosing agent were selected (D), and the RPA was calculated

TABLE 1 Demographic characteristics of the selected subjects and baseline clinical parameters grouped per treatment modality (US+P, ultrasonic debridement and abrasive paste; A+US, air polishing and ultrasonic calculus removal)

	US+P	A+US
Males (%)	21 (48.8%)	
Average age (SD)	28.4 (6.1)	
Smokers (%)	11 (22.9%)	
PPD (SD)	1.85 mm (0.79)	1.86 mm (0.80)
CAL (SD)	1.88 mm (0.80)	1.87 mm (0.82)
BoP (SD)	56.7% (49.5%)	56.9% (49.5%)
PI (SD)	65.3% (47.6%)	65.0% (47.7%)

Abbreviations: BoP, bleeding on probing; CAL, clinical attachment level; PI, plaque index; PPD, pocket probing depth; SD, standard deviation.

Very low levels of plaque are confirmed by the plaque index (PI) values at T1 and T2 (Table 4), with a statistically significant difference at 4 weeks (T2) favouring A+US treatment (12.7%[9.7; 16.5] vs. 14.7%[11.1; 19.5], ratio 0.86 [0.75; 0.98], $p = 0.023$).

Average treatment time is displayed in Table 5. A+US treatment has an average duration of 18:39 [17:42; 19:38] minutes, while US+P lasted on average 20:32 [19:30; 21:38] minutes, 9.2% longer ($p < 0.0001$).

Table 6 displays the data elaborated from the satisfaction questionnaire administered to the patients at the end of the baseline treatment. When perceived treatment quality was investigated, A+US was considered 'optimal' by 65.9% of the patients, and 70.7% of the patients preferred A+US, a significantly higher percentage than US+P (7.3%; $p = 0.0001$). Discomfort during treatment was significantly higher for the US+P group ($p < 0.0001$). 50.2% of patients scored their pain during US+P ≥ 3, with 7.5% of them reporting 'maximum discomfort'. On the other hand, only 14.6% of the patients evaluated their pain during A+US ≥ 3, with no one selecting the maximum discomfort. Based on the perceived pain, 85.4% of the patients preferred A+US. The sensation of cleanliness was high for both treatments, with more than 90% of the patients assigning a 'good' or 'optimal' score. A+US archived a significantly cleaner feeling (97.6%) than US+P (90.3%; $p = 0.0001$). 43.9% of the patients considered both treatments good in terms of final cleanliness, and 39% selected A+US as the preferred method. Considering the overall parameters questioned, a significantly higher number of patients preferred A+US to US+P (73.2% vs. 17.1%, $p = 0.0001$). 7.3% of the patients could not decide between the two, and only one patient did not like any treatment protocol. No side effects were observed or reported at any time during the study.

4 | DISCUSSIONS

Bleeding on probing (BoP) is recognized as an objective and accurate parameter to identify and grade gingivitis and is essential in assessing periodontitis treatment outcomes and residual disease risk.[1-3] Because the patients of the present study were selected

TABLE 2 Full-mouth bleeding on probing (BoP) over time and relative 95% confidence interval

	US+P [95% CI]	A+US [95% CI]	A+US/US+P [95% CI]	*p*-value
Baseline BoP	56.7% [50.7; 63.4]	56.9% [51.1; 63.5]	1.00 [0.96; 1.06]	0.85
2 weeks (T1)	7.3% [5.2; 10.2]	6.1% [4.4; 8.4]	0.84 [0.63; 1.11]	0.22
T1/baseline [95% CI]	0.13 [0.09; 0.17]	0.11 [0.08; 0.14]		
p-value T1 vs. baseline	**<0.01***	**<0.01***		
4 weeks (T2)	14.8% [10.6; 20.6]	11.2% [7.7; 16.5]	0.76 [0.63; 0.92]	**<0.01***
T2/T1 [95% CI]	2.03 [1.48; 2.79]	1.84 [1.30; 2.62]		
p-value T2 vs. T1	**<0.01***	**<0.01***		

Abbreviations: A+US, air polishing and ultrasonic calculus removal; US+P, ultrasonic debridement and abrasive paste.

*Statistically significant.

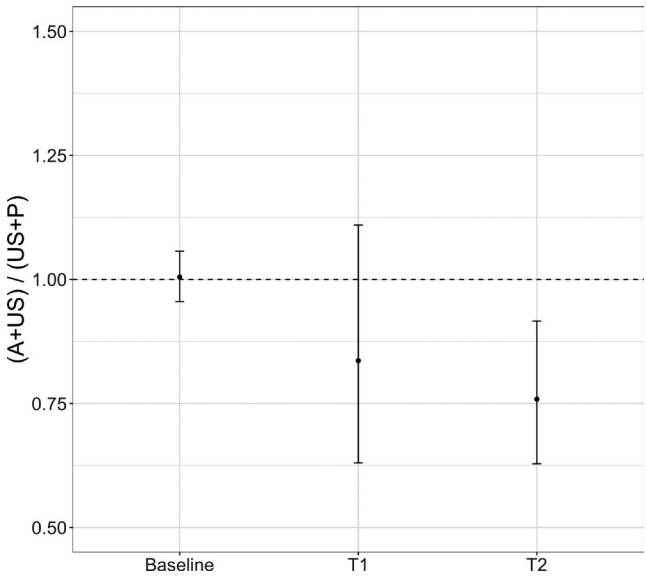

FIGURE 3 Ratio of mean BoP values between A+US and US+P group at baseline, and T1 and T2 represented by the dot, and 95% confidence intervals are represented by the vertical lines

before the new periodontal classification was released, the diagnostic criteria for gingivitis used during recruitment were BoP > 25%. Nevertheless, the following discussion refers to the new diagnostic criteria as per Trombelli et al. (2018).[2]

The results of the present study showed that both protocols allowed to achieve a significant reduction in BoP, reaching 2-week values well below the 10% threshold for diagnosis of localized gingivitis.[2] BoP increased at 4 weeks in both groups. However, the A+US treatment group maintained a BoP level lower than the US+P group (Table 2). Graphic 1 represents the ratio between mean A+US BoP-positive sites and mean US+P BoP-positive sites. The ratio is below 1, confirming the superiority of A+US in BoP reduction. Moreover, the 95% confidence intervals are entirely included in the area of the graph below 1, demonstrating that A+US achieved greater BoP reduction in all the patients of this study. Strangely, the difference in BoP did not seem to mirror a difference in sites showing plaque at T1 and T2. The mean PI at 4 weeks was higher for both groups, and slightly but significantly higher for the US+P. However, the PI difference between T1 and T2 did not result statistically significant for either group (Table 4). Nevertheless, the authors think that the slight increase in PI and BoP between 2 and 4 weeks could be due to the decrease in compliance with the oral hygiene instructions (OHI) provided at the end of the treatment session. Compliance to OHI is known to fluctuate, and repeated session of OHI is more effective in keeping the PI low.[17,18]

The reason behind the test protocol's apparent superiority in keeping PI and BoP lower is still unknown. The split-mouth design allowed to control patient-related confounding factors that might have played a role during healing (eg level of hygiene, smoking, diet). Therefore, the reason behind the difference observed in BoP and PI is to be looked for in the different therapies. A possible explanation could lie in the composition of the powder applied during air polishing. In vitro studies demonstrate that air polishing with erythritol + chlorhexidine can inhibit the bacterial re-colonization of the treated surface.[19,20] Both erythritol and chlorhexidine are known to have antibacterial effects on dental plaque. Erythritol effectively impairs oral streptococcal species' adherence to the dental surface and decreases their sucrose metabolism.[21] Erythritol also shows in vitro efficacy against *P. gingivalis*, a common periodontal pathogen.[22] Nevertheless, frequent application/administration seems to be required.[21] Chlorhexidine is well known for its broad antimicrobial spectrum and its substantivity that allows a sustained effect.[23] The authors of the present study speculate that the chlorhexidine conveyed via air polishing on the entire tooth surface and subgingivally

TABLE 3 Post-treatment residual plaque area (%) with relative 95% confidence interval, and ratio between treatments

	A+US	US+P	Ratio B/A	*p*-value US+P vs. A+US
Residual plaque area (RPA)	1.51% [1.2; 1.9]	2.96% [2.3; 3.8]	49.0%	3

Abbreviations: A+US, air polishing and ultrasonic calculus removalUS+P, ultrasonic debridement and abrasive paste.

TABLE 4 Mean plaque index (PI) values at baseline, and 2 weeks (T1) and 4 weeks (T2) and corresponding 95% confidence interval

	US+P [95% CI]	A+US [95% CI]	A+US / US+P [95% CI]	*p*-value
Baseline	65.3% [59.7; 71.4]	65.0% [60.3; 70.2]	1.00 [0.95; 1.05]	0.876
2 weeks (T1)	14.6% [11.2; 18.9]	14.9% [11.6; 19.0]	1.02 [0.84; 1.23]	0.832
T1/Baseline [95% CI]	0.22 [0.18; 0.28]	0.23 [0.18; 0.29]		
p-value T1 vs. baseline	**<0.01***	**<0.01***		
4 weeks (T2)	14.7% [11.1; 19.5]	12.7% [9.7; 16.5]	0.86 [0.75; 0.98]	**0.023***
T2/T1 [95% CI]	1.01 [0.79; 1.29]	0.85 [0.65; 1.11]		
p-value T2 vs. T1	0.92	0.24		

Abbreviations: A+US, air polishing and ultrasonic calculus removal; US+P, ultrasonic debridement and abrasive paste.

*Statistically significant.

TABLE 5 Average duration of the treatment from randomization envelope opening to the end of the instrumentation with relative 95% confidence interval, and ratio between A+US/US+P

	A+US	US+P	Ratio US+P/A+US	*p*-value US+P vs. A+US
Time (minutes)	18:39 [17:42; 19:38]	20:32 [19:30; 21:38]	9.2%	**<0.0001**

Abbreviations: A+US, air polishing and ultrasonic calculus removal; US+P, ultrasonic debridement and abrasive paste.

might have interfered with the early stages of biofilm development, delaying its maturation. Further studies including a microbiological assessment of the plaque at different time points could help shed some light on the matter.

Finally, the authors decided to administer a pre-procedural rinse with chlorhexidine not to influence the plaque composition but to reduce viable bacteria in oral aerosol during the treatment with the ultrasonic scaler and air polishing device.[24] The authors believe this is the best practice to avoid aerosol cross-contamination.

The hypothesis of a 'sustained treatment effect' is reinforced by the fact that the residual plaque was equally low in both groups at the end of the treatment. This could be due to the fact that both groups received the pre-treatment application of a plaque disclosing agent not only to instruct and motivate the patient but also to guide the removal of plaque by the operator. As shown by a recent randomized controlled clinical study by Mensi et al. (2020),[12] the guide of the disclosing agent leads to better plaque removal, especially in areas of difficult access and close to the gingival margin.

In the present study, the RPA was evaluated in the second and fifth sextants only due to the difficulty in standardizing photographs of posterior sectors taken with an extra-oral camera. Therefore, the data do not represent the real RPA, which is expected to be higher. The additional post-treatment photographs of the posterior areas, taken for clinical record but not analysed, show more residual plaque than the anterior sextants, probably due to the more difficult access during the prophylactic manoeuvres. Moreover, the present RPA measurement via software analysis does not allow to evaluate the residual subgingival plaque, which might constitute an important negative factor during healing.

Patil et al. (2015)[25] performed an analogous study, comparing air polishing to rubber cup with prophylaxis paste in terms of PI and gingival status immediately after treatment and after 15 days. While the results seem to be similar in terms of significant gingival inflammation reduction at 2 weeks for both treatments, a real comparison to the present study is difficult due to important protocol differences. In Patil et al. (2015),[25] ultrasonic calculus removal was performed

TABLE 6 Analysis of the post-treatment patient satisfaction questionnaire. The questionnaire investigated the (1) overall perceived quality of the treatment, (2) the level of discomfort during treatment, (3) the feeling of cleanliness after the treatment and (4) which treatment they would prefer to have if they could choose

	A+US	US+P	*p*-value
1. Perceived treatment quality			
Insufficient	0	0	*p*-value US+P vs. A+US[a] <0.0001
Average	1 (2.4%)	9 (22.0%)	
Good	13 (31.7%)	24 (58.5%)	
Optimal	27 (65.9%)	8 (19.5%)	
Preferred treatment	A+US: 29 (70.7%)	US+P: 3 (7.3%)	
	None: 1 (2.4%)	Both: 8 (19.5%)	
2. Discomfort during treatment			
0 (min discomfort)	12 (29.3%)	1 (2.4%)	*p*-value US+P vs. A+US[a] <0.0001
1	13 (31.7%)	5 (12.2%)	
2	10 (24.4%)	14 (34.1%)	
3	5 (12.2%)	17 (41.5%)	
4	1 (2.4%)	1 (2.4%)	
5 (max discomfort)	0	3 (7.3%)	
Preferred treatment	A+US: 35 (85.4%)	US+P: 3 (7.3%)	
	None: 1 (2.4%)	Both: 2 (4.9%)	
3. Feeling of cleanliness			
Insufficient	1 (2.4%)	1 (2.4%)	*p*-value US+P vs. A+US[a] <0.0001
Sufficient	0	0	
Average	0	3 (7.3%)	
Good	15 (36.6%)	17 (41.5%)	
Optimal	25 (61.0%)	20 (48.8%)	
Preferred treatment	A+US: 16 (39.0%)	US+P: 6 (14.6%)	
	None: 1 (2.4%)	Both: 18 (43.9%)	
4. Overall, which treatment was the preferred?			
None	1 (2.4%)		*p*-value A+US vs. US+P[b] <0.0001
US+P	7 (17.1%)		
A+US	30 (73.2%)		
Both	3 (7.3%)		

Abbreviations: A+US, air polishing and ultrasonic calculus removal; US+P–ultrasonic debridement and abrasive paste.

[a]Calculated via linear regression analysis with repeated measurements.

[b]Equality of proportion hypothesis test.

before the two interventions for both groups, the quadrants were not randomized to the treatment, and an air polishing powder made of sodium bicarbonate was used. Sodium bicarbonate is not suitable for subgingival treatment.

When investigating the patients' perception of the treatment, a clear difference could be seen between the two protocols. Table 6 displays the results of a questionnaire administered at the end of the treatment session. A+US showed a significantly lower level of discomfort, and for this reason, 85.4% of the patient preferred it to US+P. This is in line with other clinical trials on the application of air polishing for the maintenance therapy of periodontal patients, proving its higher level of comfort.[10,26] Furthermore, the patients' perceived quality of treatment and feeling of 'cleanliness' were significantly higher for A+US. Considering all the parameters, 73.2% of the present study patients selected 'A+US' as their preferred treatment method. Being pain a major factor in the development of dental anxiety and, possibly, in the loss of compliance,[27] it is important to provide our patients with the most comfortable treatment possible.

Finally, A+US treatment allowed to save on average 9.2% of the treatment time, compared with US+P. Once again, the reader must keep in mind the split-mouth design of the study. Therefore, the time displayed refers to the treatment of half the mouth only.

The present study demonstrated the non-inferiority of the A+US protocol to the traditional ultrasonic instrumentation and polishing gingivitis resolution, with additional benefits for patient comfort

and time-saving. These results, together with the body of evidence showing how air polishing is more conservative on the dental and oral tissues than ultrasonic instrumentation and polishing with abrasive paste,[7-9] make A+US a suitable protocol for the successful management of patients with plaque-induced gingivitis.

A limitation of the present study could be the selected population. While strict inclusion criteria allowed to exclude possible biases, the selected subjects might not represent the real population afferent to a general dental practice. Further studies including patients with orthodontic appliances and/or complex rehabilitations could provide more information about the tested protocol. Moreover, only light smokers (<10 cigarettes per day) were included, as smoking could influence the level of BoP.[28]

Another limitation is the RPA software analysis, which, even if very objective and precise, allows to analyse only photographs of the second and fifth quadrant, possibly missing important data regarding residual plaque in the posterior sectors of the mouth. Moreover, the analysis performed on 2D images does distinguish between thin or thick layers of plaque or the presence of calculus, limiting the ability to distinguish between patients with similar distribution but a different level of plaque and calculus control. A limitation of the test treatment could be the cost of accessing new air polishing equipment, compared with the relatively cheap rubber cups and abrasive paste. However, the time saved and the increased comfort and related patient satisfaction represent the main return of investment. Moreover, air polishing has some limitations, such as the application on patients with severe asthma and other respiratory diseases.

5 | CONCLUSION

In conclusion, the present study demonstrates that the A+US protocol, involving the use of air polishing followed by ultrasonic removal of calculus, is suitable for the short-term resolution of plaque-induced gingivitis. 4 weeks after treatment, A+US leads to a higher reduction in BoP than traditional ultrasonic scaling and polishing with rubber cup and abrasive paste. Additional benefits are a shorter treatment time and superior comfort.

6 | Clinical relevance

6.1 | Scientific rationale for study

To compare the traditional dental prophylaxis method with a new approach based on the use of full-mouth air polishing followed by targeted ultrasonic calculus removal.

6.2 | Principal findings

The tested protocol is suitable for the treatment of gingivitis, as well as time-saving and comfortable for the patient.

6.3 | Practical implications

Professionally, prophylaxis can be enhanced with the application of air polishing and targeted ultrasonic instrumentation.

CONFLICT OF INTEREST

Dr. Mensi reports personal fees from EMS, personal fees from KULZER and personal fees from SUNSTAR outside the submitted work. Dr. Sordillo reports personal fees from EMS Electro Medical Systems, during the conduct of the study. Dr. Scotti, Dr. Dalè and Dr. Calza have nothing to disclose.

AUTHOR CONTRIBUTIONS

MM designed the study. SE and DM were the principal investigators. SA wrote the article. CS performed the statistical analysis.

DATA AVAILABILITY STATEMENT

Data are available on request from the authors.

ORCID

Magda Mensi https://orcid.org/0000-0001-5807-9338

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