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ORIGINAL ARTICLE

The effects of a desiccant agent in the treatment of chronic periodontitis: a randomized, controlled clinical trial

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Abstract
Objective Chemotherapeutic agents have been widely used as adjuncts for the treatment of chronic periodontitis (CP). This study investigated and compared a desiccant agent as an adjunct to scaling and root planing (SRP) versus SRP alone for the treatment of CP.
Materials and methods Thirty-six patients with CP were studied. Using a split-mouth design, the maxillary right and left quadrants were randomly assigned to SRP plus desiccant (Hybenx® EPIEN Medical, Inc. St. Paul, MN, USA) or SRP alone. Patients were examined on a regular basis for clinical, microbiological, and inflammatory mediator changes over a 1-year period. Clinical attachment level (CAL) was the primary outcome variable. In addition, the red complex bacteria and gingival crevicular fluid (GCF) inflammatory mediators were monitored.
Results Compared to baseline, both treatments demonstrated an improvement in periodontal parameters. Compared to SRP alone, SRP plus desiccant yielded a significant improvement in probing depth (PD) (SRP: 2.23 ± 0.31 mm vs. desiccant: 3.25 ± 0.57 mm, $p < 0.05$), CAL (SRP: 3.16 ± 0.29 mm vs. desiccant: 4.21 ± 0.34 mm, $p < 0.05$ mm) and bleeding on probing (BOP) (SRP: 4.56 ± 1.5% vs. desiccant: 34.23 ± 4.2%, $p < 0.001$) at 12 months. Similarly, in the SRP plus desiccant group, the bacteria of the red complex were significantly reduced ($p < 0.05$); and the level of inflammatory mediators was significantly reduced ($p < 0.003$) compared to SRP alone.
Conclusions SRP plus the desiccant resulted in a greater reduction in clinical, microbial and inflammatory mediators compared to SRP alone.
Clinical relevance Desiccant, when combined to SRP, was demonstrated as a significant approach to control the levels of certain periodontal pathogens, inflammatory mediators in patients with CP.

Keywords Chronic periodontitis · Desiccants · Local delivery · Scaling and root planing · Randomized controlled trials · Microbiology

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Introduction

Chronic periodontitis (CP) is an inflammatory disease caused by oral biofilms that often lead to destruction of the supporting tissues of teeth, and eventually tooth loss [1–3]. The success of CP therapy depends mostly on the effective removal of supra- and subgingival bacterial biofilms with the relative

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smear layer which contains bacteria, endotoxins, and contaminated cementum [4, 5].

Nonsurgical periodontal treatment, which aims to reduce pathogenic supra/subgingival biofilms by mechanical instrumentation, has been shown to have limited effect in deep pockets [6]. Although systematic reviews have shown an improvement in clinical periodontal parameters [6, 7], scaling and root planing (SRP) does not entirely remove periodontal pathogens, particularly in deep periodontal pockets [8] because it does not eradicate all periodontal pathogens involved in CP [9, 10]. In fact, it was reported that the persistence of certain periodontal pathogens, such as the bacteria of the orange and red complex, can lead to residual periodontal pocketing and persistent or rebound inflammation after mechanical debridement [11].

Given the important role played by microorganisms in the development and progression of CP, there is an increasing interest in adjunctive therapies that could improve the outcomes of SRP in CP patients by reducing the periodontal pathogens specifically. For many years, in addition to SRP, systemic and locally delivered antibiotics have been used to suppress the biofilm [12]. Amoxicillin plus metronidazole as an adjunct to mechanical debridement has been shown to be effective in controlling periodontal pathogens; however, there was difficulty in maintaining a stable therapeutic concentration of anti-microbial agent, together with a potential risk of producing resistant microorganisms or patient-related adverse effects [13–15]. In light of these limitations, complementary protocols have been suggested for the treatment of CP.

The microorganisms in the biofilms live in a biomatrix, which prevents antimicrobial agents from reaching the intended bacterial targets in the subgingival area [16]. Over time, strategies such as local delivery controlled release systems were developed.

For many years, a desiccant agent has been used in dentistry for the treatment of aphthous stomatitis [17]. Subsequently, a new generation of desiccant was synthetized to replace the previously used. This desiccant is a simple liquid solution that contains a concentrated blend of sulphonic/sulphuric acids [18]. These acids have a strong affinity to bind to the water present in the biofilm matrix and to quickly detach, destroy, and eradicate the biofilm [18].

In a pilot study, desiccant plus ultrasonic debridement was effective in dissolving the biofilm and enhancing the effectiveness of SRP [19]. Moreover, encouraging results were reported by a preliminary study of Bracke et al. [20] which showed that the adjunctive use of desiccant to SRP was useful in reducing the mean levels of certain periodontal pathogens and reduced inflammatory mediators during periodontal therapy. In light of these findings, the aim of the present study was to further evaluate the effect of SRP plus desiccant on clinical parameters, microbial profiles and inflammatory mediator levels compared to SRP alone for the treatment of CP at 1-year follow-up. The null hypothesis to invalidate was that, after a 1-year follow-up, there were no variations between SRP plus desiccant and SRP alone.

Materials and methods

Ethical issues

The local ethical committee of the University of Messina approved the study protocol (#919-10). The study was registered at clinicaltrials.gov (ID: NCT02657096). Each patient was informed about the possible risks of the study and provided informed written consent.

Study design

Patients with a diagnosis of CP [21] were enrolled in this randomized, split-mouth, controlled clinical trial. The inclusion criteria were (1) good general health, (2) a minimum of six teeth per quadrant, respectively [22], (3) a minimum of 2 teeth in each quadrant with a probing depth (PD) ≥5 mm, (4) ≥40% sites with bleeding on probing (BOP), and (5) no involvement of furcations. The exclusion criteria were (1) periodontal therapy during the last 12 months, (2) use of antibiotics during the last 6 months, (3) pregnancy, (4) any systemic condition which might affect the study, (5) previous or current radiation or immunosuppressive therapy, (6) use of mouthwash containing antimicrobials during the previous 3 months, (7) use of hormonal contraceptives, (8) medication by anti-inflammatory and immunosuppressive drugs, (9) previous history of excessive drinking, (10) smoking, and (11) class II and III tooth mobility.

Study sample

Thirty-six patients, 19 men and 17 women, aged 27 to 65 (mean age 46.7) were assessed for eligibility at the School of Dentistry of the University of Messina, Messina, Italy (Fig. 1). This trial was conducted in agreement with the CONSORT guidelines [23].

Clinical examinations

A full-mouth periodontal evaluation was achieved in all patients. The same masked examiner (GM) not involved in the treatment performed all probing measurements on six sites per tooth. BOP and presence of gingival recession (GR) were recorded during the PD assessment by evaluating the possible presence of bleeding up to 30 s, then probing with a periodontal probe (UNC-15, Hu-Friedy, Chicago, IL, USA). Following completion of the clinical assessments during the calibration sessions, intra-examiner repeatability and reproducibility of

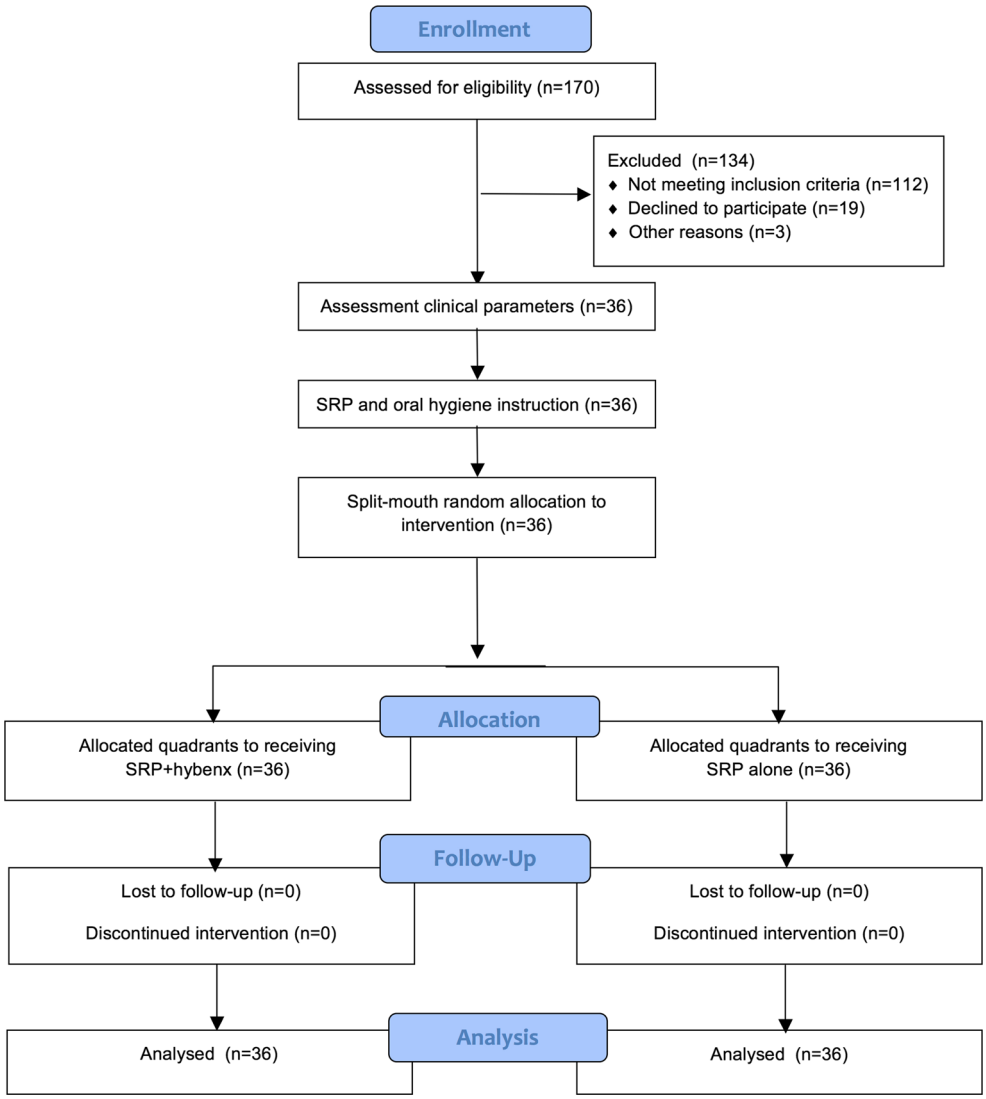

Fig. 1 Flowchart of the randomized clinical split-mouth study design

clinical attachment level (CAL) was evaluated in order to obtain duplicate measurements of the clinical parameters from randomly selected patients. Intra-examiner agreement was calculated by Cohen's k coefficient, which was 0.812, that predicted a good degree of reliability. The kappa coefficients were calculated for the measurements obtained at each different examination. Good reliability (ICC = 0.769) was found for all examinations.

After admission to the study, at every appointment, each patient was instructed in oral hygiene and appropriate motivation.

Treatment

Clinical data were recorded in all patients which included PD, BOP, CAL, GR, and plaque score obtained for the maxillary teeth [24]. CAL was recorded as PD plus recession (fixed at the cemento-enamel junction) (Table 1). Both quadrants included maxillary teeth 11–16 and 21–26. The evaluations were at baseline and at days 15, 30, 60, 180, and 365 (last follow-up).

A clinician, not involved in the trial, generated a random quadrant allocation sequence by a ratio of 1:1 using a permuted block design by a computer random-number generator. In every patient, the upper maxillary quadrants were allocated to receive SRP + desiccant or SRP alone treatment.

The allocation concealment to the therapist was performed through serially numbered sealed envelopes and the details of the sequence were unidentified to the clinicians participating in the study. Before every treatment, an investigator not involved in the recording and processing of data performed the assignment of the sealed envelopes marked with the initials of the name and date of birth of the patient and containing treatment methods for the therapist for each quadrant.

Shortly before each treatment session, another clinician opened the envelope with the assigned number by which the

Table 1 Clinical parameters for the tests and control groups at baseline and 365 days and the results of intergroup comparisons

	PD (mm)		CAL (mm)		BOP (%)		Plaque Score (%)		GR (mm)	
Treatment	SRP + HBX	SRP alone	SRP + HBX	SRP alone	SRP + HBX	SRP alone	SRP + HBX	SRP alone	SRP + HBX	SRP alone
Baseline	4.96 ± 0.66	5.05 ± 0.57	5.1 ± 0.44	4.95 ± 0.61	68.81 ± 2.8	69.12 ± 2.6	29.21 ± 6.04	28.36 ± 6.85	0.13 ± 0.11	−0.07 ± 0.03
15 days	4.12 ± 0.52	4.95 ± 0.57	5.04 ± 0.41	4.91 ± 0.51	35.56 ± 3.5*	52.89 ± 4.8	27.33 ± 7.21	27.97 ± 7.67	0.76 ± 0.26	−0.04 ± 0.09
30 days	3.84 ± 0.54	4.35 ± 0.57	4.72 ± 0.39	4.86 ± 0.45	26.64 ± 3.4*	51.32 ± 4.5	26.33 ± 5.09	27.65 ± 5.55	0.84 ± 0.35*	0.31 ± 0.21
60 days	2.42 ± 0.36*	4.35 ± 0.57	3.64 ± 0.42*	4.79 ± 0.48	15.45 ± 2.4*	43.32 ± 2.6	26.11 ± 6.69	27.21 ± 5.96	0.81 ± 0.37*	0.49 ± 0.38
180 days	2.11 ± 0.33	2.75 ± 0.24	3.16 ± 0.21	3.05 ± 0.28	11.23 ± 3.1*	26.67 ± 3.6	23.67 ± 4.49	28.15 ± 4.86	0.89 ± 0.28*	0.25 ± 0.13
365 days	2.23 ± 0.31*	3.25 ± 0.57	3.16 ± 0.29*	4.21 ± 0.34	4.56 ± 1.5*	34.23 ± 4.2	17.12 ± 5.37	22.78 ± 5.34	0.77 ± 0.29	0.94 ± 0.48
p value	0.002	0.128	0.014	0.792	<0.001	0.002	0.071	0.136	0.064	0.129

p value, ANOVA for repeated measure for variation of clinical parameters over time

*$p < 0.003$

quadrant would subsequently be identified. The operator was informed and performed one of the two types of treatment. The same operator performed all the procedures and was blinded to previously recorded data thus avoiding bias in the evaluation of the experimental data.

Each patient, after recording periodontal parameters, underwent one of the two following treatments: one maxillary quadrant was treated with desiccant + SRP (Fig. 2), while the contra-lateral quadrant was treated with SRP alone. All the patients received full-mouth SRP and were aware that local anesthesia could be used if needed. In the quadrant assigned to desiccant + SRP treatment, desiccant (Hybenx® EPIEN Medical, Inc. St. Paul, MN, USA) was applied before SRP into the periodontal pocket with a 60-s duration and then thoroughly rinsed with a sterile saline solution. SRP was performed by trained periodontist using both hand (Gracey curettes, ASA Dental, Bozzano, Italy) and ultrasonic instruments by tip No. 5/6/7 (Satelec Ultrasonics, Acteon, VA, Italy). The ultrasonic device was used with a frequency of 6000 Hz and constant water irrigation according to the manufacturer's instructions. The mean time needed in the SRP group was 9 min per quadrant.

The contra-lateral quadrant was treated only with SRP. In this group, irrigation with saline solution was used for 60 s in order to mask the desiccant treated sites. At the end of treatment, patients were asked to discontinue tooth brushing on the day of the treatment period. For the following 14 days after treatment, all patients were enrolled in a hygiene program according to individual needs and received oral domiciliary hygiene instructions. Subsequently, the patients were instructed to adopt the manual tooth brushing with the modified Bass technique and by the use of the dental floss. No antiplaque and anti-inflammatory mouthwashes or any kind of antibiotics were prescribed after treatment. At each follow-up session, adverse effects were noted, and supragingival deposits, if found, were removed.

Biological samples

In all patients, subgingival plaque was acquired from six separate proximal sites at baseline and at 15, 30, 60, 180, and 365 days after therapy. To permit specimen analysis, all sites chosen were isolated using cotton rolls. Subsequently, a sterilized paper point was introduced into the base of the selected site for 30 s, and a subgingival plaque sample collected. The samples were stored in sterile Eppendorf vials with 0.15 mL of a solution of sterilized phosphate-buffered saline (PBS), then stored at −80 °C. In all samples, 40 microbial species were counted and investigated using the checkerboard DNA–DNA hybridization technique described by Socransky et al. [25]. Subsequently, whole genomic DNA probes to 40 subgingival species were digoxigenin-labeled and hybridized in separate lanes of the miniblotter. Following hybridization, the

membranes were rinsed, and the DNA probes were identified. An antibody conjugated with digoxigenin and alkaline phosphatase used chemiluminescence exposure, transformed to absolute counts, comparing the regression line which resulted from the values on the same membrane as previously described [26]. If the signal was not perceived, it was documented as 0. For each run, two lanes comprised standards at concentrations of 10^5 and 10^6 cells of all the microbial species analyzed. The test sensitivity was corrected in order to allow the recognition of 10^4 cells for each microbial type through correcting the concentration of all DNA probes.

Gingival crevicular fluid (GCF) was obtained at the same time from six other different non-contiguous interproximal sites using filter paper strips (Periopaper, Oraflow, NY, USA) as previously described [27]. The GCF volume of each strip was determined by an electronic gingival fluid measuring device (Periotron 8000, Oraflow, NY, USA) in picograms (pg)/microlitre. The strips were placed into sterile microtube vials and kept at −70 °C until analyzed and the strips contaminated with blood were discarded. The levels of interleukin (IL) -1β, IL-10, and tumor necrosis factor (TNF)-α were measured by enzyme-linked immunosorbent assay (ELISA). The amount of total protein of each sample was determined using commercially available kits (HSCYTMAG-60SK MilliplexMAP, Merck Millipore, Billerica, MA). The levels of the cytokines IL-1b, IL-10, and TNF-α in GCF samples were determined using high-sensitivity kits (MAGPIX analyzer) and the multiplexing instrument in accordance to the recommendations of the manufacturer. The concentrations of each cytokine were estimated from the standard curve using a five-parameter polynomial equation.

Sample size calculation

The sample size was established considering an effect size of 0.40 with $\alpha = 0.050$ and a power level of 0.80 for the CAL parameter that was the primary outcome variable chosen. It was determined that a minimum sample of 23 quadrants per group would be needed, considering that some patients could be lost during the 1-year follow-up. Thirty-six patients were enrolled, so that the primary variable, CAL, achieved a power value of 0.90.

Statistical analysis

Examined data were normally distributed, such as verified by Kolmogorov-Smirnov test; consequently, we applied a parametric approach for data analysis. Since a split mouth design was realized, differences between SRP + desiccant and SRP alone were evaluated using Students *t* test for paired samples, for each follow-up session (Table 1). For the clinical parameters analysis, measured over time, all test units were obtained from the average of six measurements per treated tooth and at

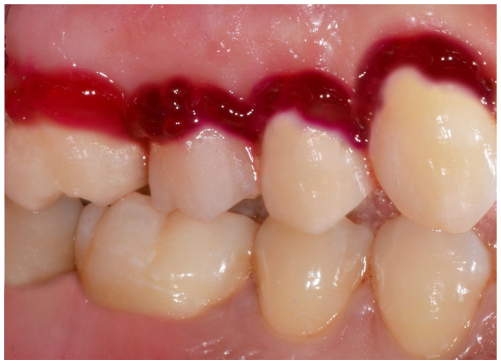

Fig. 2 Application of desiccant gel in the SRP + desiccant quadrants group

a minimum of six teeth per treated quadrant. The variation of clinical parameters over time was evaluated by ANOVA for repeated measure (Table 1). Adjustment for multiple comparisons was used; the significance level 0.050 was divided for 15 (i.e., the number of possible pairwise comparisons between the six follow-up sessions) so that the effective adjusted *p* value was considered significant when <0.003. The patient's maxillary quadrant was set as a test unit for statistical analysis and evaluation (Table 2).

Microbial data is presented as mean counts ($\times 10^5$) of each microbial species; values were expressed as mean ± standard error of the mean (SEM). The significant differences in each group for mean counts of all microbial species were detected by the Students *t* test for paired samples test and analyses were performed after corrections for multiple assessments as previously described [28].

Total protein values were converted to picograms per milliliter (pg/ml). The final cytokines levels analyzed were obtained by the values initially resulting from the multiplexing system from the total protein amount in GCF (picograms per milliliter), and the IL-1β/IL-10 ratio was estimated per quadrant group by ANOVA for repeated measure [29]. Differences between quadrants during all experimental periods and among quadrants for the mean concentrations of IL-1β, IL-10, and TNF-α were calculated by two-way ANOVA and a post hoc Bonferroni test. All statistical analyses were executed using a software program (SPSS 17.0 for Window package, IBM, Chicago, IL, USA). $p < 0.05$ was considered to be statistically significant.

Results

All patients originally enrolled completed the study. Mean values (±standard deviation, SD) of PD, CAL, BOP, and plaque score are presented in Table 1. The postoperative course was unremarkable in all patients during the 1-year follow-up without any adverse events such as abscesses or infections.

No significant differences were observed between groups at baseline for the clinical, microbiological, and immunological parameters. We found that both treatments, SRP + desiccant and SRP alone produced a significant reduction of every periodontal parameter compared to the values recorded at baseline ($p < 0.05$) (Table 1). Comparison over time shows that in the SRP + desiccant group, significant differences exist for PD ($p = 0.002$) and BOP ($p < 0.001$); in SRP alone there was a significant reduction for only BOP values ($p = 0.002$) (Table 1). At 15, 30, 60, and 180 days, there was no significant difference between the two treatments for PD, CAL, and plaque score values. SRP + desiccant therapy significantly reduced at 15 and 180 days ($p < 0.05$) and highly significantly reduced at 30 and 60 days ($p < 0.001$) for the BOP values compared to SRP alone. Moreover, the SRP + desiccant group presented significant differences at 30, 60, and 180 days ($p < 0.003$) for the GR values compared to SRP alone. However, compared to SRP alone, SRP + desiccant yielded a significant probing depth (PD) reduction (SRP: 2.23 ± 0.31 mm vs. desiccant: 3.25 ± 0.57 mm, $p < 0.05$), CAL gain (SRP: 3.16 ± 0.29 mm vs. desiccant: 4.21 ± 0.34 mm, $p < 0.05$ mm), bleeding on probing (BOP) reduction (SRP: 4.56 ± 1.5% vs. desiccant: 34.23 ± 4.2%, $p < 0.001$) at 12 months (Table 1). The gingival recession was significantly improved compared to baseline but not significantly different between groups at 12 months (SRP: 0.94 ± 0.48 mm vs. desiccant: 0.77 ± 0.29 mm, $p = 0.06$) as well as the plaque score (SRP: 22.78 ± 5.34% vs desiccant: 17.12 ± 5.37%, $p = 0.06$) (Table 1).

Figure 3 presents the changes in the proportions of periodontal pathogens at baseline and at days 15, 30, 60, 180, and 365 in the SRP + desiccant and SRP alone group. Of the 40 microbial species evaluated at each time point, the SRP + desiccant group showed significant reductions ($p < 0.001$) in species of the orange complex at 60 (*Fusobacterium vicentii*), 180 (*Fusobacterium nucleatum* and *Fusobacterium periodonticum*), and 365 days (*F. nucleatum*, *F. polymporphum*, *F. periodonticum*, *Treponella intermedia*) compared to the SRP alone group (Fig. 3). Furthermore, there was a significant decrease in the number of the red complex species (*Porphyromonas gingivalis*, *Tannerella forsythia*, *Treponema denticola*) in the SRP + desiccant group compared to the SRP alone group at 15 (*T. forsythia*, *P. gingivalis*, $p < 0.001$), 30 (*T. forsythia*, *T. denticola*, $p < 0.05$; *P. gingivalis*, $p < 0.001$), 60 (*T. forsythia*, *P. gingivalis*, *T. denticola*, $p < 0.001$), and 180 days (*T. forsythia*, *P. gingivalis*, $p < 0.001$; *T. denticola*, $p < 0.05$). At 1 year, these results were still highly statistically different for all species of the red complex ($p < 0.001$).

GCF volumes were significantly reduced in both groups after treatment compared to baseline ($p < 0.001$). The mean GCF value at baseline was 0.51 ± 0.14 pg/ml in the SRP + desiccant group and 0.43 ± 0.11 pg/ml in the SRP alone group. After 1-year follow up, these values were 0.17 ± 0.06 pg/ml and 0.16 ± 0.06 pg/ml, respectively. No statistically significant differences were observed in GCF volumes between two different groups ($p < 0.05$). Figure 4 presents the distribution of the mean values of GCF cytokines. There was a statistically significant reduction of the mean GCF values due to the treatment response in both groups from baseline to the last follow-up. However, the SRP + desiccant group at 15 and 365 days had a mean level of IL-1β which was significantly reduced compared to the SRP alone group ($p < 0.05$). There were highly significant differences for the mean levels of IL-10 that was statistically higher in the SRP + desiccant quadrant at 60, 180 ($p < 0.001$), and 365 days ($p < 0.05$) compared to the SRP alone group (Fig. 4). TNF-α mean level was significantly lower in the SRP + desiccant group, at 30 ($p < 0.05$), 60, and 180 ($p < 0.001$) and at 365 days ($p < 0.05$) and the IL-1β/IL-10 ratio was significantly lower, at 60 ($p < 0.05$), 180, and 365 days in the SRP + desiccant group compared to SRP alone ($p < 0.001$).

Discussion

This randomized split-mouth clinical trial compared the effect of SRP alone versus SRP plus desiccant using clinical, microbiological, and inflammatory mediator analyses in patients with CP.

Both treatments improved the clinical, microbiological, and inflammatory mediator outcomes. However, the SRP + desiccant treatment led to a statistically significant improvement, at 12 months, of the PD and BOP compared to the SRP alone.

One of the key points of both surgical and nonsurgical periodontal therapy in CP patients is to reduce the subgingival bacterial burden, a critical step that has been shown for periodontal tissue long-term healing and repair in CP therapy [30–32].

For several decades, SRP has frequently been enhanced by the use of antimicrobial agents such as antiseptics and systemic or locally delivered antibiotics [33, 34]. However, it has also been reported that periodontal pocket bacteria may become increasingly resistant to antibiotics [13, 35]. Thus, greater efforts are being made to find new treatment strategies that may not rely on antibiotics [36, 37].

Our research has focused on the novel desiccant, which is a concentrated aqueous mixture of sulphonic and sulphuric acid that possesses a desiccating and denaturing action on biofilms [18–20]. Thus, desiccant can potentiate the effects of SRP of periodontal pockets by promoting the reduction of all bacteria including periodontal pathogens that are contained within the periodontal pocket biofilm [38]. This action should enhance the clinical effect of SRP. Our study demonstrated that, at

Table 2 Absolute and percentage changes (mean ± SD) of the clinical and laboratory parameters of treatment groups between baseline and 365 days follow-up

	SRP + HBX		SRP alone		Intergroup Comparison		*p* value
Parameter	Change from baseline	% of change	Change from baseline	% of change	Change from baseline	% of change	
PD reduction (mm)	2.73 ± 0.65**	−55.04 ± 0.34	1.8 ± 0.52	−25.74 ± 0.54	0.93 ± 0.45	−29.3 ± 0.56	<0.001
CAL gain (mm)	1.94 ± 0.33*	−38.03 ± 0.39	0.74 ± 0.42	−14.94 ± 0.39	1.2 ± 0.42	−23.09 ± 0.41	<0.001
BOP reduction (%)	64.24 ± 3.4**	−93.37 ± 15.43	34.87 ± 4.2**	−50.46 ± 4.4	29.37 ± 3.9	−73.7 ± 7.9	<0.001
FMPS reduction (%)	12.09 ± 22.98*	−41.38 ± 21.23	5.58 ± 18.83	−19.67 ± 17.56	6.51 ± 19.65	−21.71 ± 18.46	0.193
IL-1β levels (pg/ml)	12.34 ± 6.21**	−68.36 ± 6.36	9.21 ± 8.12*	−49.43 ± 7.45	3.13 ± 6.08	−18.93 ± 7.84	0.070
IL-10 levels (pg/ml)	8.31 ± 1.4**	65.8 ± 1.5	2.12 ± 1.2*	39.06 ± 1.7	6.2 ± 1.3	26.74 ± 1.5	<0.001
TNF-α levels (pg/ml)	1.6 ± 0.4*	46.8 ± 0.9	1.5 ± 0.6	−36.58 ± 0.7	0.1 ± 0.4	10.22 ± 0.9	0.408

*$p < 0.05$, **$p < 0.001$

1 year, when desiccant was combined with SRP, there was a significant decrease in PD compared to SRP alone.

Lombardo et al. have reported that when desiccant was applied into the periodontal pocket as an adjunct to SRP, there was a decrease of 0.87 ± 1.3 mm in PD and reduction of the bacterial load at 3 months in patients with moderate to severe CP [19].

Based on the pilot observation by Lombardo et al. [19], we designed the current study to compare the clinical, microbiological, and inflammatory effects of SRP + desiccant or SRP alone in a 1-year study.

In the present study, the mean reduction of PD in the test group at 60 days after treatment was greater than the reduction that occurred in the SRP alone group (0.93 mm) and that increased up to 2.73 ± 0.65 mm at 12 months compared to baseline and 0.93 ± 0.45 mm compared to SRP alone.

Our findings are consistent with those reported in a recently published case series showing that desiccant provides significant clinical benefits as a therapy to another periodontal condition, the acute periodontal abscess [39].

Desiccant is not been well studied and its mechanism of action is not completely understood. The effects of desiccant

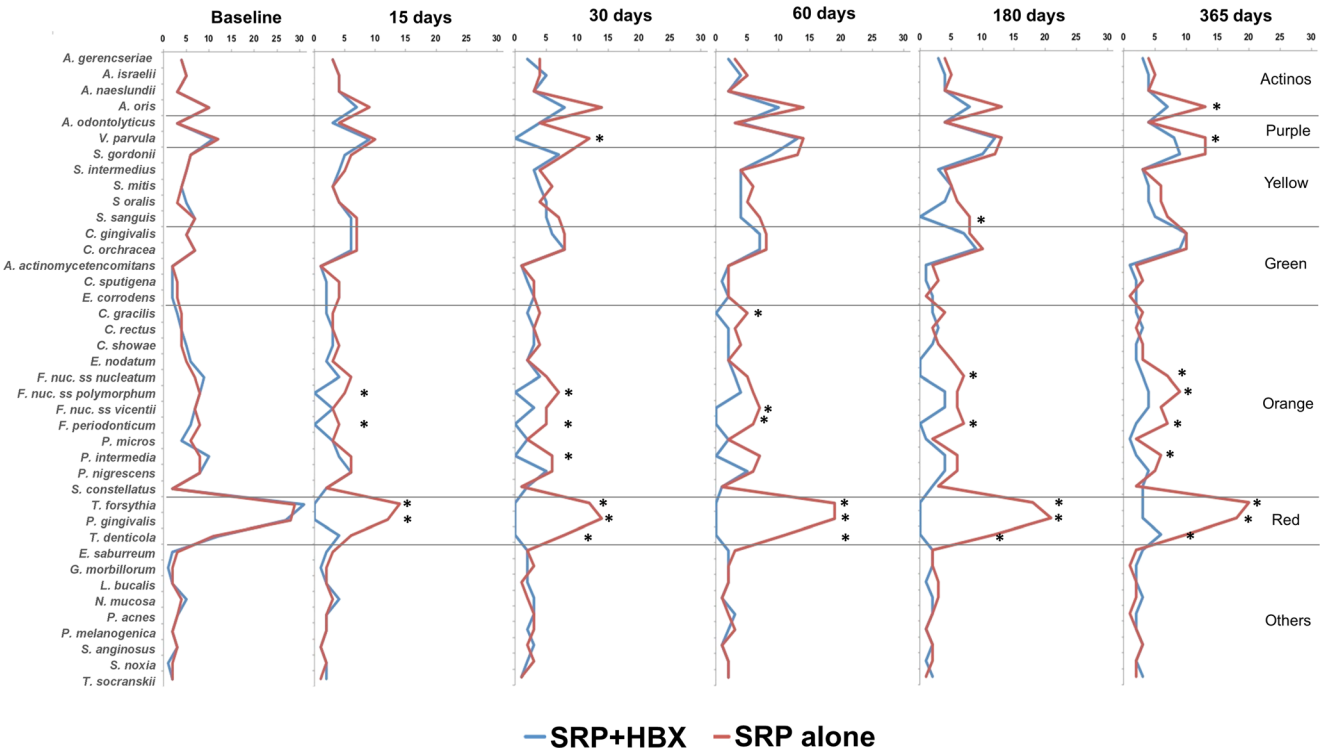

Fig. 3 Mean counts (×10^5) of 40 bacterial species in the SRP + desiccant and SRP alone groups at baseline and 15, 30, 60, 180, and 365 days and the results of intergroup comparisons. The species were ordered according to the microbial complexes described by Socransky et al. (1998). *$p < 0.05$

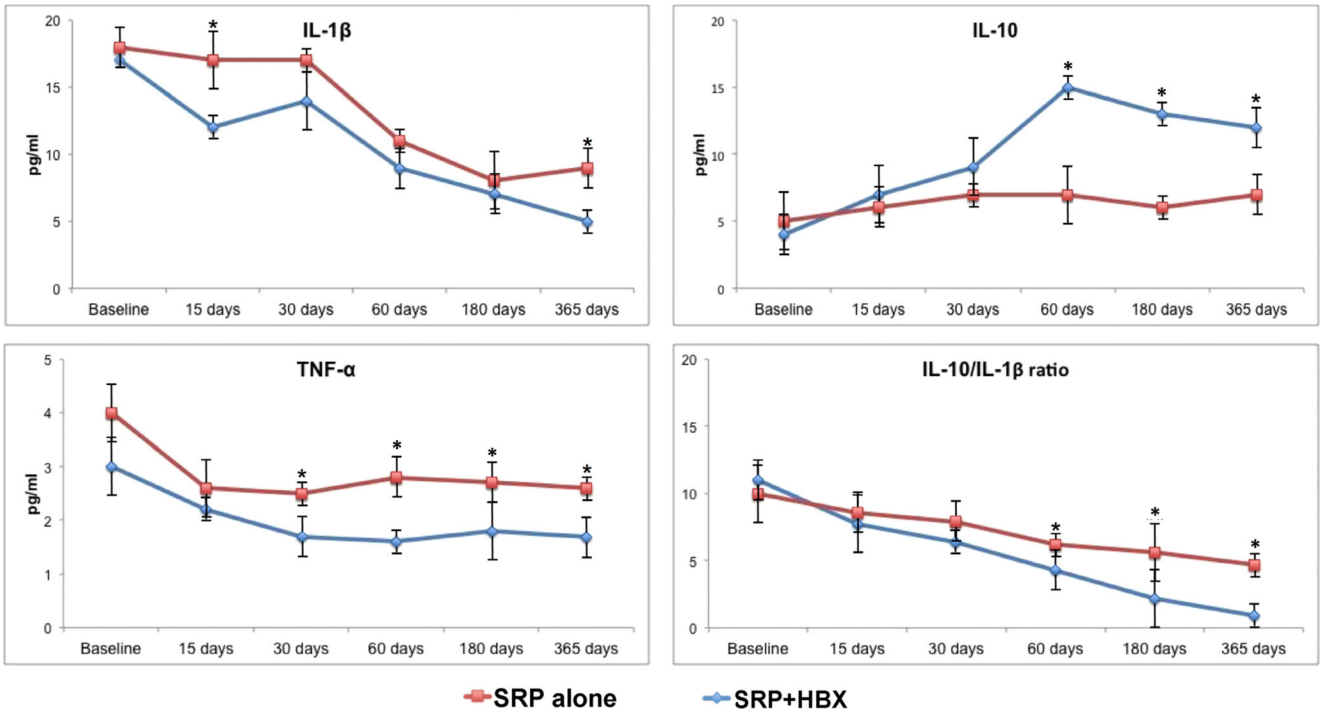

Fig. 4 Mean levels (picograms per milliliter) of IL-1β, IL-10, and TNF- α and IL-1β/IL-10 ratios at baseline and at 15, 30, 60, 180, and 365 days in the SRP + desiccant group and SRP alone group. *$p < 0.003$ between groups in the same period of analysis, Wilcoxon test

may be due to the ability of the solution to actively detach biofilms from the site of infection; this is believed to exert a superficial molecular denaturation and tissue coagulation of the superficial layer of periodontal tissue; this rapid irreversible desiccation mechanism allows the action of hand or ultrasound instrumentation to more easily remove the biofilm [19, 39].

Moreover, it was showed that a desiccant agent has a strong contact on biofilm and dentin [19], so it might be hypothesized that the application of desiccant on the cervical dentin could result in increased tooth pain and hypersensitivity. When patients were asked to refer their perception after the periodontal treatment, they indicated that their postoperative course was unremarkable during the 1-year follow-up without any important adverse events. Only 4 patients presented, at the first follow-up session (15 days), a lower degree of dentinal hypersensitivity on the SRP plus desiccant quadrant compared to SRP alone.

Moreover, SRP plus desiccant, reduced the percentage of bleeding sites (BOP) compared to SRP alone (29.37 ± 3.9%) at 1-year follow up. Absence of BOP is a useful indicator of periodontal health [40, 41]. In agreements with the results of previous reports, the reduction of BOP may be associated with the desiccant and chemical coagulating action on biofilm exerted by desiccant [19, 20].

Concerning microbiological parameters, the SRP + desiccant treated group presented reduced proportions of many bacteria from the orange and red complexes in the short and long-term follow-up when compared to SRP alone. It is important to emphasize that a strong reduction of these periodontal pathogens, especially the red complex bacteria, is one of the key factors in the clinical success of nonsurgical periodontal therapy [34, 42]. In fact, previous reports highlighted that gram-negative bacteria, existing in periodontal pockets, are difficult to eliminate [42, 43].

The ability of desiccant to strongly reduce periodontal pathogens has been previously demonstrated by clinical studies [19, 20]. Desiccant therapy was reported to affect, in CP patients, after 6 weeks of application, the anaerobic bacterial load compared to SRP alone [19]. The microbiological results of our study demonstrated, using the checkerboard DNA–DNA hybridization technique, that the adjunctive use of desiccant to SRP was capable of significantly reducing the proportion of certain periodontal pathogens such as *T. forsythia*, *P. intermedia*, and *P. gingivalis* ($p < 0.001$). This reduction was comparable to the results reported by Dastoor et al. [44] and Mascarenhas et al. [45] after 3 months of systemic use of Azithromycin as an adjunct to SRP.

This study also indicated that SRP + desiccant significantly reduced the GCF levels of the IL-1β/IL-10 ratio compared to SRP alone ($p < 0.001$) at 1-year follow-up. Previous investigators have suggested that a higher IL-1β/IL-10 ratio may be correlated with elevated proportions of periodontal pathogens of the orange and red complex [46, 47].

The reduction in periodontal pathogens found in the SRP + desiccant group may have influenced the GCF level reductions

of pro-inflammatory cytokines as demonstrated by the reduction of TNF-α levels compared to SRP alone. Increasing evidence indicates that periodontal tissue loss is caused more by the host response than from direct bacterial damage and TNF-α was showed to play a critical role in stimulating the innate host response and to prepare the host defense against periodontopathogenic bacteria [48]. If present at high levels in the GCF, it was clearly demonstrated that TNF-α plays a central role in the inflammatory reaction, in alveolar bone resorption and in the loss of connective tissue attachment [48, 49].

During recent years, a number of antimicrobial agents, as adjunct to SRP, have been studied for the effect on CP therapy. There is ongoing research to develop and examine new agents that can help in the reduction of the biofilm without causing resistance of plaque microorganisms. Identifying new agents should be encouraged in order to find alternative treatment strategies to antibiotics or antiseptics.

This study indicated that, when the desiccant is used as an adjunct to SRP, there was a significant effect in the clinical, microbial and inflammatory parameters compared to SRP alone. Desiccant was demonstrated as a safe and simple adjunct to SRP in the treatment of CP.

This initial study of desiccant is promising and demands further studies to better understand the role and potential benefits of desiccant in the treatment of periodontal disease.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The local ethical committee of the University of Messina approved the study protocol (#919-10).

Informed consent Informed consent was obtained from all individual participants included in the study.

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