



# Efficacy of periimplant mechanical debridement with and without adjunct antimicrobial photodynamic therapy in the treatment of periimplant diseases among cigarette smokers and non-smokers



Fawad Javed<sup>a,\*</sup>, Tariq Abduljabbar<sup>b</sup>, Gabriela Carranza<sup>a</sup>, Elham Gholamiazizi<sup>c</sup>, David K. Mazgaj<sup>a</sup>, Sergio Varela Kellesarian<sup>a</sup>, Fahim Vohra<sup>b</sup>

<sup>a</sup> Department of General Dentistry, Eastman Institute for Oral Health, University of Rochester, NY, USA

<sup>b</sup> Department of Prosthetic Dental Sciences, College of Dentistry, King Saud University, Riyadh, Saudi Arabia

<sup>c</sup> Department of Mechanical Engineering, Capital College, Pennsylvania State University, PA, USA

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## ABSTRACT

**Objective:** The aim was to assess the efficacy of mechanical debridement (MD) with and without adjunct antimicrobial photodynamic therapy (aPDT) in reducing periimplant inflammation among cigarette-smokers and non-smokers.

**Methods:** Cigarette-smokers and non-smokers were randomly divided into 2 groups. In the test-group, participants underwent full mouth scaling and periimplant MD with adjunct aPDT; and in the control-group, the participants underwent full mouth scaling and periimplant MD alone. Periimplant bleeding on probing (BOP), probing depth (PD) and crestal bone loss (CBL) were measured at baseline and at 6- and 12-months follow-up. Statistical analysis was performed using the Kruskal-Wallis test. P-values < 0.05 were considered statistically significant.

**Results:** Eighty-four smokers (41 patients in the test group and 43 in the control group) and 82 non-smokers (40 patients in the test group and 42 in the control group) were included. Among smokers and non-smokers, periimplant PD was significantly higher in the control-group compared with the test-group (P < 0.05) at 6-months of follow-up. There was no statistically significant difference in BOP, PD and CBL among smokers and non-smokers in the test- and control-groups at 12-months of follow-up. BOP was comparable among smokers at all time intervals.

**Conclusion:** In the short-term, MD with adjunct aPDT is more effective in reducing periimplant probing depth than MD alone in smokers and non-smokers. However, in the long-term outcomes of MD either with or without aPDT among smokers and non-smokers are comparable.

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## 1. Introduction

It is well-established that tobacco smoking is associated with the etiology of peri-implant diseases, peri-implant mucositis and periimplantitis [1]. Moreover, rates of failure of osseointegration have also been reported to be significantly higher in smokers compared with non-smokers [2]. In the study by Cavalcati et al. [3], rates of implant failure after 5 years of loading were nearly twice as high in smokers compared with non-smokers. One explanation on this regard is that nicotine enhances the accumulation of the oral biofilm thereby increasing inflammation and microbial accumula-

tion in the periimplant tissues [4]. In addition, scores of periimplant soft tissue inflammatory parameters gingival index, probing depth [PD] and peri-implant bone loss are higher in smokers than non-smokers [5]. According to Tsigarida et al. [6], smoking influences the peri-implant microbiomes (even in clinically healthy individuals), by promoting a pathogen-rich community in the periimplant tissues. Furthermore, levels of destructive inflammatory cytokines such as interleukin-1 beta, tumor necrosis factor-alpha (TNF- $\alpha$ ), and prostaglandin E2 in the peri-implant sulcular fluid have been reported to be higher in smokers than non-smokers [5]. In this regard, treatment of periimplant diseases in smokers may challenge clinicians and researchers.

Traditionally, mechanical debridement (MD) of periodontal and periimplant tissues is performed for the treatment of periodontal and periimplant diseases, respectively [7,8]; however, studies

\* Corresponding author.

E-mail address: [fawad.javed@urmc.rochester.edu](mailto:fawad.javed@urmc.rochester.edu) (F. Javed).

[8–10] have shown that MD when performed with adjunct therapies such as antimicrobial photodynamic therapy (aPDT), is more effective in the treatment of periodontal and periimplant diseases compared with MD alone. aPDT involves interactions between a light source and a photosensitizer (such as methylene blue and toluidine blue), in an aerobic environment. This results in the generation of free oxygen radicals that damage target cells such as tumor and bacterial cells [11]. aPDT has also been reported to kill pathogenic microbes associated with the etiology of periodontal and periimplant disease such as *Aggregatibacter actinomycetemcomitans* (*A. actinomycetemcomitans*), *Prevotella intermedia*, and *Porphyromonas gingivalis* (*P. gingivalis*) [12].

Since outcomes of periodontal therapeutic interventions are compromised in tobacco-smokers compared with non-smokers [13]; it is hypothesized that in smokers, there is no statistically significant difference in the outcomes of MD either with or without aPDT compared with non-smokers; and MD with adjunct aPDT is more effective in the treatment of periimplant diseases among non-smokers compared with MD alone. The aim of the present study was to assess the efficacy of periimplant MD with and without adjunct aPDT in the treatment of periimplant diseases among cigarette-smokers and non-smokers.

## 2. Materials and methods

### 2.1. Ethical guidelines

The study was approved by the Research Ethics Review committee of the College of Dentistry, King Saud University, Riyadh, Saudi Arabia. Volunteering individuals were requested to read and sign a consent form. All participants were informed that they reserved the right to withdraw their participation at any stage of the investigation without consequences.

### 2.2. Inclusion and exclusion criteria

The inclusion criteria were as follows: (a) cigarette smokers (individuals who reported to be smoking at least 1 cigarette daily since at least 1 year; (b) non-smokers (individuals who reported to have never consumed any form of tobacco product); (c) patients with periimplant diseases (periimplant bleeding on probing [BOP] in at least 30% sites and probing depth [PD] of at least 4 mm); (d) signing the consent form. Pregnant and/or lactating females, habitual alcohol users, patients with systemic diseases such as diabetes mellitus, acquired immune deficiency syndrome and renal disorders and patients who reported to have used antibiotics, corticosteroids and nonsteroidal anti-inflammatory drugs within the past 90 days were excluded.

### 2.3. Grouping and randomization

Participants (smokers and non-smokers) were randomly divided into 2 groups. In the test-group, participants underwent full mouth SRP and MD of periimplant surfaces with adjunct aPDT; and in the control-group, the participants underwent full mouth SRP including MD of periimplant tissues. Randomization was done by tossing a coin.

### 2.4. Questionnaire

A questionnaire was used to gather information regarding age, gender, number of cigarettes smoked daily, duration of smoking habit (in years), number of implants placed, duration of implants in function (in years) and implant loading protocol (immediate or delayed).

### 2.5. Assessment of periimplant clinical and radiographic parameters

All clinical and radiographic examinations were performed by a trained and calibrated investigator. The overall kappa for intra-examiner reliability was 0.88. Peri-implant BOP [14] and PD [15] were measured at six sites per implant (mesiobuccal, mid-buccal, distobuccal, distolingual/palatal, midlingual/palatal and mesiolingual/palatal). Peri-implant PD was measured to the nearest millimeter using a graded probe (Hu-Friedy, Chicago, IL, USA) [16]. In both groups, intra-oral digital bitewing radiographs were taken for each implant. The radiographic technique was standardized by using a film holder as a guiding tool for X-ray beams (Belmont ACURAY 071A Intra Oral X-Ray System, Hudson, FL, USA). Crestal bone loss (CBL) was defined as the linear distance from the implant-abutment junction to the most coronal part of the alveolar crest [17]. CBL was recorded in millimeters using a software program (Scion Image, Scion Corp., Fredrick, Maryland, USA).

### 2.6. Follow-up

Follow-up examinations were performed at 6- and 12-months, in which periimplant BOP, PD and CBL were assessed among all individuals

### 2.7. Statistical analysis

Statistical analysis was performed using a software program. In the test- and control groups, the Kruskal-Wallis test was used to compare the periimplant BOP, PD and MBL at 6 and 12-months follow-up. Sample size estimation was performed with a computer software (nQuery Advisor 5.0, Statistical Solutions, Saugus, Massachusetts, USA). Power analysis was based on the supposition that a mean difference of 0.5 mm and 1 mm in peri-implant CBL and PD, respectively should be detected between patients in the test and control groups at a significance level of 0.05 to attain a desired study power of at least 80%. It was estimated that a sample size of 40 individuals per group will achieve a power of 88% with a 0.05 two-sided significance level. P-values less than 0.05 were considered statistically significant.

## 3. Results

### 3.1. General characteristics of the study cohort

In total, 84 smokers (41 patients in the test group and 43 in the control group) and 82 non-smokers (40 patients in the test group and 42 in the control group) were included. The male:female ratio of participants in the test and control groups among smokers and non-smokers was 28:13 and 32:11 and 30:10 and 30:12, respectively. The mean ages of smokers and non-smokers in the test and control groups were 40.5 and 38.6 years and 41.6 and 40.2 years, respectively. Among smokers, the mean duration of smoking habit was 14.6 and 15.5 years among individuals in the test- and control groups, respectively; and the mean numbers of cigarettes smoked daily among patients in the test and control groups were 11.3 and 13.4 cigarettes, respectively. Among smokers, a total of 66 and 59 implants had been placed among patients in the test and control groups, correspondingly; and among non-smokers, a total of 61 and 63 implants had been placed. Among smokers and non-smokers, the implants in the test- and control groups had been in function since 4.4 and 5.2 years and 3.7 and 4.5 years, respectively (Table 1). All implants were delayed-loaded platform-switched implants and had moderately rough surfaces. In both groups, the diameters and

**Table 1**  
General characteristics of studies included.

	Cigarette smokers (n = 84)		Non-smokers (n = 82)	
	Test-group (MD + aPDT)	Control group (MD alone)	Test-group (MD + aPDT)	Control group (MD alone)
Number of individuals	41	43	40	42
Gender (Male:Female)	28:13	32:11	30:10	30:12
Mean age in years (range)	40.5 (28–54)	38.6 (30–52)	41.6 (26–55)	40.2 (28–51)
Mean duration of smoking habit	14.6 (10–32)	15.5 (11–35)	–	–
Mean number of cigarettes smoked daily	11.3 (8–30)	13.4 (10–25)	–	–
Number of implants	66	59	61	63
Duration of implants in function in years (range)	4.4 (2–7)	5.2 (3–6)	3.7 (1–5)	4.5 (2–5)

lengths of implants ranged between 3.5–4.1 mm and 11–14 mm, respectively.

### 3.2. Clinical and radiographic parameters of the study cohort

#### 3.2.1. Smokers

Compared with baseline, there was no statistically significant difference in BOP among smokers in the test- and control-groups at 6- and 12-months of follow-up (Fig. 1). Periimplant PD was statistically significantly higher at baseline compared with 6- and 12-months of follow-up among smokers and non-smokers (Fig. 2). At 6-months of follow-up, periimplant PD was significantly higher in the control-groups compared with the test-group ( $P < 0.05$ ). There was no statistically significant difference in PD among smokers in the test- and control-groups at 12-months of follow-up (Fig. 2).

#### 3.2.2. Non-smokers

BOP was significantly higher among individuals in the test and control groups at baseline compared with 6- ( $P < 0.05$ ) and 12-months ( $P < 0.05$ ) follow-up. At 6-months of follow-up, BOP ( $P < 0.05$ ) (Fig. 1) and PD ( $P < 0.05$ ) (Fig. 2) were statistically significantly higher among individuals in the control group compared with the test-group ( $P < 0.05$ ). At 12-months follow-up, there was no statistically significant difference in BOP among patients in the test- and control-groups (Fig. 1).

#### 3.2.3. Smokers versus non-smokers

At baseline, percentage of sites with BOP were statistically significantly higher among non-smokers in the test- and control-groups compared with smokers ( $P < 0.05$ ) (Fig. 1). There was no statistically significant difference in BOP and PD among smokers and non-smokers in the test- and control-groups at 12-months of follow-up (Figs. 1 and 2). There was no statistically significant difference in CBL among smokers and non-smokers in the test- and control groups at all time intervals (Fig. 3).

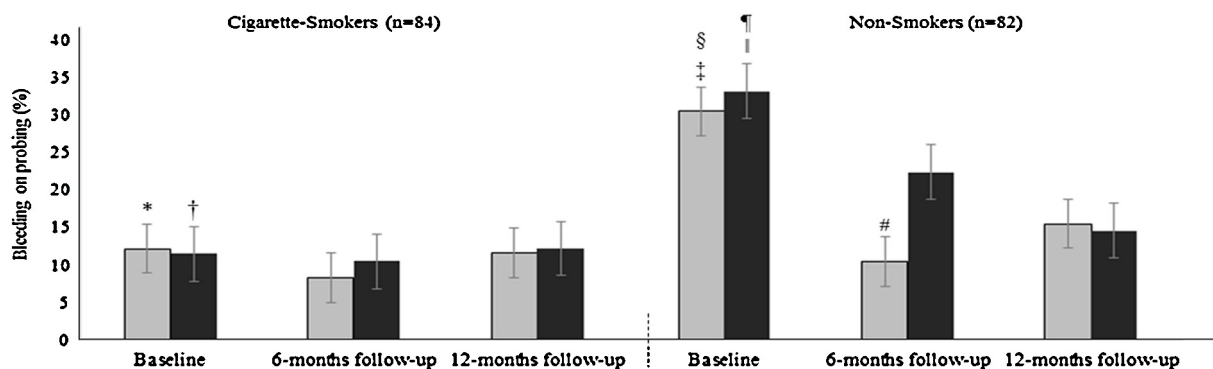
## 4. Discussion

To our knowledge, this is the first study that compared the efficacy of MD with and without adjunct aPDT in the treatment of periimplant diseases among smokers and non-smokers. In the present study, it was hypothesized that (a) there is no statistically significant effect of MD either with or without aPDT in the treatment of periimplant diseases among smokers; and (b) MD with adjunct aPDT is more effective in the treatment of periimplant diseases among non-smokers compared with MD alone. Interestingly, the present results showed that in the short-term (at 3-months of follow-up) MD with adjunct aPDT was more effective in reducing periimplant PD compared to MD alone in smokers as well as non-smokers; however, in the long-term (6-months follow-up), the outcomes of MD either with or without aPDT was comparable among smokers and non-smokers. One explanation in this regard could be derived from the study by Eick et al. [18], which showed

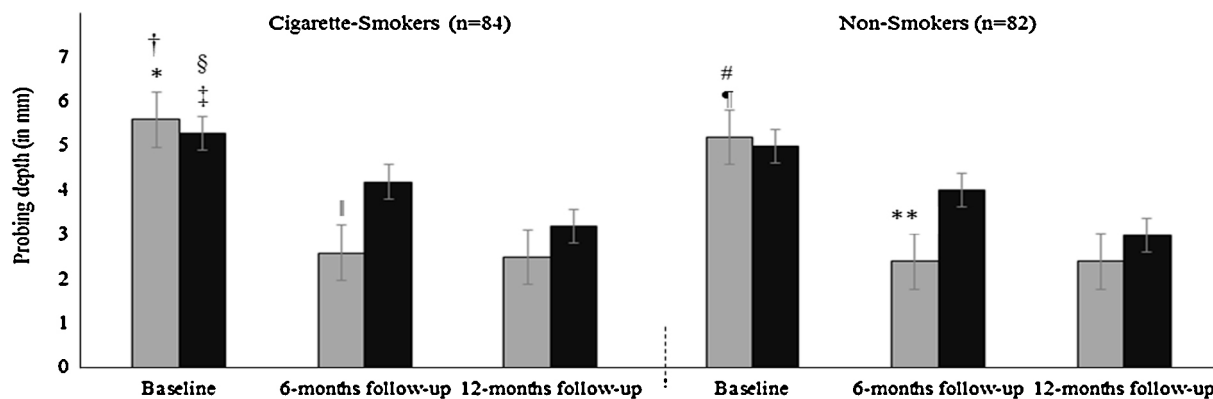
that although aPDT is effective against pathogenic microbes such as *A. actinomycetemcomitans* and *P. gingivalis*, and can reduce viability in biofilms, aPDT is unable to completely destroy complex biofilms. Similarly, in the study by Dörtbudak et al. [19], aPDT significantly reduced the counts of *A. actinomycetemcomitans* and *P. gingivalis* around implant surfaces; however a complete eradication of microbes could not be achieved. Moreover, it has also been shown that SRP with adjunct aPDT moderately decreases the levels of destructive inflammatory cytokines such as TNF- $\alpha$ , interleukin-1 beta and matrix metalloproteinase (MMP)-8 and MMP-9 in the gingival crevicular fluid compared with SRP alone [20]. The present study supports the results of a systematic review in which, the authors concluded that the efficacy of aPDT in the treatment of periimplant diseases is debatable [21]. However, in the present study, there were no adverse effects associated with the use of PDT, which is in accordance with previous studies [20,22].

In the present study, BOP at baseline was statistically significantly higher among non-smokers compared with non-smokers; however, there was no statistically significant difference in BOP among smokers at all time intervals. It is well-known that tobacco smoking masks the clinical signs of oral inflammation by reducing BOP. Grudianov and Kemularia [23] used laser Doppler flowmetry to investigate gingival microcirculation in smokers. The results showed that smoking decreases gingival blood flow in smokers compared with non-smokers [23]. Since smokers continued to smoke cigarettes throughout the study period, it is possible that due to the vasoconstrictive effect of nicotine on gingival blood vessels, BOP remained masked in smokers throughout the study period. However, the reduction in PD among smokers at 3-months of follow-up could be associated with MD as well as the anti-inflammatory effect of free oxygen radicals generated as a result of aPDT. The same explanation can be posed for the reduction of PD in non-smokers at 3-months of follow-up. These results are in accordance with a previous study [24]. There was no statistically significant difference in CBL among smokers and non-smokers in both groups throughout the study period. One explanation in this regard is that the present study at a 12-month follow-up period, which seems to be insufficient to assess significant differences in crestal bone levels following MD with or without aPDT. Moreover, MD with and without aPDT was done once in the present study. Furthermore, all participants included in the present investigation had periimplant mucositis. It is therefore hypothesized that if the study had a longer follow-up duration (at least 2 years) and MD with and without aPDT was done at 6-months follow-up, a difference in periimplant soft tissue inflammatory parameters (BOP and PD) might have been observed among the test- and control groups. In addition, further studies on smokers and non-smokers with periimplantitis are warranted to assess whether or not MD with adjunct aPDT enhances new bone formation around implants.

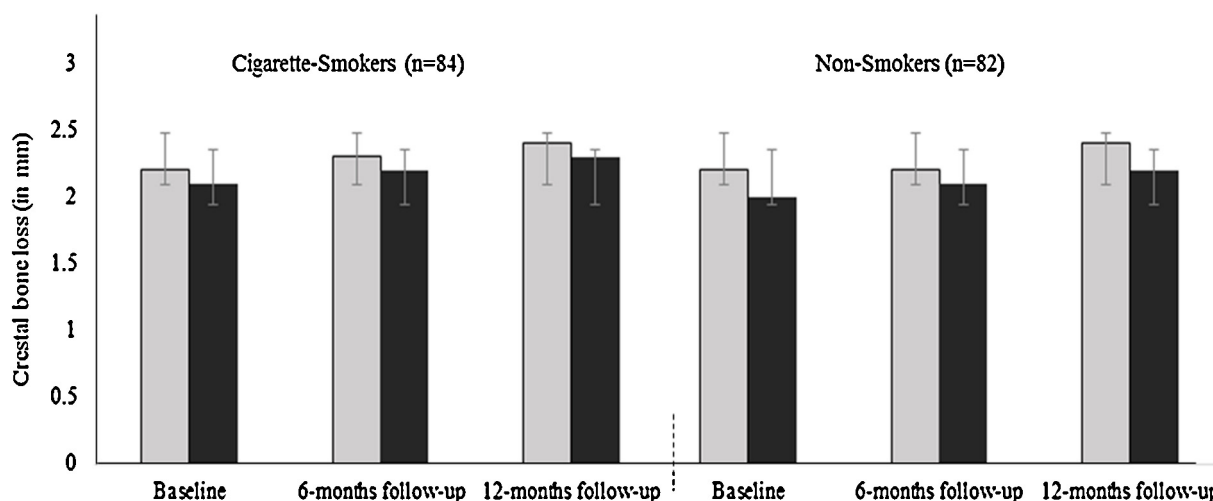
The limitations of the present study are that none of the participants had periimplantitis, all participants were relatively young (approximately 40 years old) and all implants had been in function for relatively short durations (approximately 4 years). Further



**Fig. 1.** Periimplant bleeding on probing at baseline and after 6- and 12-months of follow-up among smokers and non-smokers in the test- (light grey bars) and control-groups (black bars). \*Compared with the test-group among non-smokers at baseline ( $P < 0.05$ ); †Compared with the control-group at baseline ( $P < 0.05$ ); ‡Compared with the test-group at 6- ( $P < 0.05$ ) and 12-months ( $P < 0.05$ ) of follow-up; §Compared with the control-group at 6- ( $P < 0.05$ ) and 12-months ( $P < 0.05$ ) of follow-up; ¶Compared with the test-group at 6- ( $P < 0.05$ ) and 12-months ( $P < 0.05$ ) of follow-up; ¶Compared with the control-group at 6- ( $P < 0.05$ ) and 12-months ( $P < 0.05$ ) of follow-up.



**Fig. 2.** Periimplant probing depth at baseline and after 6- and 12-months of follow-up among smokers and non-smokers in the test- (light grey bars) and control-groups (black bars). \*Compared with the test-group at 6- ( $P < 0.05$ ) and 12-months ( $P < 0.05$ ) of follow-up; †Compared with the control-group at 6- ( $P < 0.05$ ) and 12-months ( $P < 0.05$ ) of follow-up; ‡Compared with the control-group at 6-months of follow-up ( $P < 0.05$ ); ¶Comparad with the test-group at 6- ( $P < 0.05$ ) and 12-months ( $P < 0.05$ ) of follow-up; #Compared with the control-group at 6- ( $P < 0.05$ ) and 12-months ( $P < 0.05$ ) of follow-up; \*\*Compared with the control-group at 6-months of follow-up ( $P < 0.05$ ).



**Fig. 3.** Periimplant crestal bone loss at baseline and after 6- and 12-months of follow-up among smokers and non-smokers in the test- (light grey bars) and control-groups (black bars).

long-term follow-up studies among smokers and non-smokers with periimplantitis are therefore warranted. It is however, highly recommended that patients should be educated regarding the detrimental effects of smoking on overall health and anti-tobacco campaigns can be useful in this regard.

## 5. Conclusion

In the short-term, MD with adjunct aPDT is more effective in reducing periimplant probing depth than MD alone in smokers and non-smokers. However, in the long-term outcomes of MD either

with or without aPDT are comparable among smokers and non-smokers.

### Conflict of interest statement

The authors declare that they have no conflict of interest related to the present study.

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