Association of Preventive Maintenance Therapy Compliance and Peri-Implant Diseases: A Cross-Sectional Study

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Background: This study aims to investigate association between peri-implant maintenance therapy (PIMT) and the frequency of peri-implant diseases and to further identify factors that contribute to failure of PIMT compliance.

Methods: A cross-sectional study on patients who were healthy and partially edentulous was conducted. They were grouped in the following categories according to PIMT compliance: 1) regular compliers (RC) (≥2 PIMT/year); 2) erratic compliers (EC) (<2 PIMT/year); and 3) non-compliers (NC) (no PIMT). Radiographic and clinical analyses were carried out including probing depth (PD), plaque index (PI), bleeding on probing (BOP), mucosal redness (MR), suppuration (SUP), keratinized mucosa dimension, and marginal bone loss. A multiple logistic regression model was estimated at implant and patient level to obtain adjusted odds ratios (ORs) and to control possible confounding effects among variables.

Results: Overall, 206 implants in 115 patients fulfilled inclusion criteria. At patient level, it was shown that association between compliance and peri-implant condition was statistically significant ($P = 0.04$). Compliance was associated with 86% fewer conditions of peri-implantitis. The probability of PIMT compliance was substantially associated with frequency of peri-implantitis (OR = 0.13, $P = 0.01$). Patients with a history of periodontal disease multiplied their probability of being EC (versus NC) 4.23 times with respect to not having a history of periodontal disease ($P = 0.02$). Moreover, light smokers significantly resulted to be NC compared with RC ($P = 0.04$) and EC ($P = 0.02$). Nevertheless, mucositis was not found to be statistically associated with level of compliance. In addition, PD, PI, BOP, MR, and SUP varied significantly according to PIMT compliance and peri-implant condition.

Conclusions: Peri-implant maintenance compliance ≥2 PIMT/year seems to be crucial to prevent peri-implantitis in healthy patients. Furthermore, history of periodontal disease and disease severity, as well as its extent and a smoking habit, appear to be factors that influence the compliance risk profile (NCT02789306). *J Periodontol 2017;88:1030-1041.*

KEY WORDS

Dental implants; maintenance; mucositis; peri-implantitis; periodontitis; risk factors.

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Lack of supportive periodontal maintenance therapy has been demonstrated to be strongly associated with tooth mortality.[1-4] Hence, it has been suggested that a professional mechanical plaque removal treatment must be programmed to prevent periodontal tissue breakdown.[5] Nevertheless, early studies in the field of periodontology pointed out that ≈80% of patients do not adhere to a regular schedule, with only 16% being compliers after active periodontal therapy.[1,2] It was further shown that implementing efforts in identifying and targeting erratic and non-complying individuals with more information could increase compliance to 32%.[6] Biologic plausibility remains due to three dominant facts: 1) in susceptible hosts, plaque and its byproducts represent the primary etiology of periodontal disease;[7] 2) after episodes of inflammation, periodontal tissues are moderately more susceptible due to changes in gene expression that are not encoded by DNA itself;[8] and 3) recolonization of putative bacteria such as spirochetes and motile rods occurs as soon as 4 to 8 weeks after active periodontal treatment.[9]

Likewise, peri-implant diseases are defined as plaque-induced chronic inflammatory conditions.[10] Peri-implant maintenance therapy (PIMT) has been strongly encouraged according to patient risk profiling, with 5- to 6-month recall intervals being suggested for non-susceptible individuals.[11] In this context, it was reported that peri-implantitis

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prevalence for individuals adhering to PIMT was 18%, whereas for non-compliers (NC), it was 43.9%.[12] Moreover, unawareness of peri-implant diseases by many practitioners might not help to highlight the importance of post-implant therapy enrollment on maintenance programs for long-term success.[13] Interestingly, non-compliance rate seems to increase during a 3-year period from 5% to 13%, with NC having a worse prognosis than well-maintained individuals.[14]

Although the impact of supportive periodontal therapy and recall interval has been correlated with periodontal disease progression and tooth loss,[4,15] there is still a lack of information on its implication on peri-implant diseases. As such, this study aims to investigate association between PIMT and frequency of peri-implant diseases and to further identify individual risk profiles that contribute to failure of PIMT compliance.

MATERIALS AND METHODS

The present cross-sectional study was conducted in accordance with the Helsinki declaration of human studies and received approval from the ethics committee of the University of Extremadura, Badajoz, Spain, and the International University of Catalunya, Barcelona, Spain from May 2016 to March 2017. A clinical and radiographic cross-sectional study was conducted in two private practices devoted exclusively to periodontics and implantology (AM [Badajoz, Spain] and JN [Barcelona, Spain]). Each participant enrolled in the present study gave informed written consent. Moreover, this study was registered and approved by Clinicaltrials.gov (NCT02789306). This study was reported in accordance with the Analysis Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement.[16]

Study Population

A total of 115 patients (69 males and 46 females, aged 23 to 79 years; mean age: 57.1 ± 10.0 years) met the inclusion criteria. All enrolled participants had to be consecutively treated with dental implants for fixed prosthesis rehabilitation, with a minimum period of 36 months after final prosthesis delivery. Patients were contacted and informed about participation in clinical and radiographic assessment to identify the presence of peri-implant diseases. Eligible implants had to be in an ideal prosthetically driven implant position; otherwise, they were excluded from analysis. Moreover, implants that could not have an accurately recorded probing depth (PD) due to inadequate prosthesis design were further excluded. Baseline periapical x-ray at the time of prosthesis delivery was retrospectively assessed to exclude implants with early peri-implant bone loss before function. The high relevance of enrolling a strict PIMT was highlighted to prevent peri-implant diseases at treatment planning presentation. In addition, a detailed description of risk factors and indicators of peri-implant disease was explained at the same appointment. Patients with active periodontal disease were treated or referred for proper diagnosis and treatment tailored according to need. All eligible implant patients were placed on a 5- to 6-month recall schedule. Patients with a history of periodontal disease, smoking, or other local conditions associated with peri-implant pathology (e.g., mucositis) were encouraged to attend a 3-month recall program alternating with the referring general dental practitioner. Additionally, patients were thoroughly instructed on plaque control home-care strategies including, but not limited to, interdental brushes with nylon-coated core wire, soft toothbrushes (manual and power), and floss with a stiffened end to clean under multiple-unit fixed prostheses.

Eligibility Criteria

Patients were either approached during their biannual PIMT appointment or contacted and asked to participate in free clinical and radiographic examination to identify possible presence of peri-implant pathology. To attract NC patients for study, emphasis was made on the high frequency of peri-implant diseases and importance of early diagnosis to ultimately prevent implant loss.

The following inclusion criteria were applied: 1) patients aged 18 to 80 years who were healthy and partially edentulous (American Society of Anesthesiologists (ASA) I-II); 2) non- or light smokers (<10 cigarettes/day); 3) no presence of infectious diseases at time of implant placement or during PIMT; 4) implants placed in pristine bone; 5) no presence of serious disease or condition known to alter bone metabolism (osteoporosis, renal disease, oncologic condition, and/or treatment or disturbance of calcium metabolism); and 6) patients with stable periodontal condition with or without history of chronic periodontitis. On the contrary, individuals were excluded for the following reasons: 1) pregnancy; 2) history of heavy smoking; 3) uncontrolled medical conditions such as diabetes mellitus (DM); 4) inadequate implant position (i.e., prosthetically driven); 5) implant not properly restored impeding accurate PD recording; 6) cement-retained restorations; or 7) lack of minimal band of 2 mm of keratinized mucosa (KM).

Study Outcomes

The primary outcome of the present study is to analyze frequency of peri-implant diseases at implant and patient level according to their compliance with professional oral health care after implant placement. As secondary outcomes, it aims to identify frequency of compliance and to further assess individual risk profiles that contribute to failure of PIMT compliance.

Study Groups

Sample size calculation was based on Cohen F test to achieve power of 80% at effect size and probability

level of 0.05 with confounding factors and covariates. Therefore, patients were grouped as regular compliers (RC), erratic compliers (EC), or non-compliers (NC), as described elsewhere.[2] As such, complete compliance was based on the longest PIMT recall interval possible for each group.

Groups were:

- RC = 3- to 6-month recall interval (≥2 PIMT/year)
- EC = 7- to 12-month recall interval (<2 PIMT/year)
- NC = no recall interval program (no PIMT/year)

Patients who participated in a recall schedule but discontinued PIMT in future appointments were categorized as EC or NC according to their compliance during the following years.

Peri-Implant Maintenance Therapy Protocol

Review of medical and dental history was performed, followed by clinical evaluation of implant(s) and, if needed due to presence of apparent inflammation, combined with deep PD (>5 mm); a periapical radiograph was taken to evaluate peri-implant bone level. Briefly, during regular PIMT appointments, oral hygiene was assessed in the remaining dentition and dental implants by means of plaque and debris accumulation. Therapy provided at the maintenance appointment included removal of plaque and calculus, utilizing curets, plastic-tip ultrasonic devices, and rubber cup low-speed polish as suggested elsewhere by the *American Academy of Periodontology* position paper.[17] Furthermore, interdental brushes with nylon-coated core wire along with floss with a stiffened end were used to thoroughly remove any biofilm attached to interproximal subgingival areas. An explorer instrument was used to check complete removal of biofilm on the implant surface. Chlorhexidine 0.12% was provided to rinse for 30 to 40 seconds after therapy was concluded. Behavior modification (tobacco cessation, oral hygiene instruction, and systemic factor counseling) was addressed based on patient findings.

Case Definition of Mucositis

As suggested by the *American Academy of Periodontology* position paper[18] and the VIII European Federation of Periodontology,[10] mucositis was defined as an inflammatory condition that courses with swelling (tumor) and bleeding in the lack of radiographic peri-implant marginal bone loss (MBL). As such, implants with no bleeding, or only bleeding on probing (BOP) at one surface assuming a point of bleeding as a consequence of trauma from probing, no suppuration (SUP), and bone loss <2.0 mm, were considered healthy. On the other hand, overt bleeding[19] (at least two sites to exclude positive BOP as a consequence of trauma from probing)[20] or tissue edema with minimal isolated (one site per implant) or no SUP was defined as mucositis.

Case Definition of Peri-Implantitis

Definition of peri-implantitis was based on clinical inflammation combined with radiographic bone loss. Accordingly, peri-implantitis was defined as the presence of clinical inflammation in combination with radiographic bone loss >2 mm, as earlier proposed by the VIII European Workshop on Periodontal Diseases by the European Federation of Periodontology.[10] The landmark used to evaluate peri-implant bone level was the neck in the case of rough full-bodied implants or the rough-to-smooth interface in the case of tissue-level implants. As such, signs such as presence of SUP, BOP, redness, and PD were recorded at six sites per implant applying 0.15 N/cm force as suggested by the *American Academy of Periodontology* position paper.[18]

Radiographic Assessment

Peri-implant MBL was determined by taking linear measurements from the most mesial and distal points of the implant neck to the crestal bone on each periapical radiograph, corrected according to known height and width of each implant using image software.§ For tissue-level implants, the interface between rough–smooth surfaces was taken as reference to assess MBL. Moreover, a baseline x-ray (after prosthesis delivery) was obtained from records to measure biologic width establishment (physiologic MBL) to determine progressing bone loss as a consequence of an inflammatory condition (i.e., peri-implantitis).

Clinical Assessment

The following clinical parameters were recorded: 1) PD; 2) plaque index (PI);[21] 3) BOP; 4) presence of mucosal redness (MR); and 5) SUP. All these aforementioned parameters were recorded at six sites per implant, and KM at buccal and lingual aspects was recorded. History of periodontal disease, severity (mild, moderate, severe), and extent (localized, generalized) were further recorded from patient records according to the *American Academy of Periodontology* Task Force Classification (2016).[22] In addition, the habit of light smoking (<10 cigarettes/day) was monitored to study association with compliance and peri-implant diseases.

Statistical Analyses

Data were calculated at patient and implant level. Inferential analysis was carried out, including estimation of simple binary logistic regression models with dependent variable level of compliance (RC versus EC, RC versus NC, EC versus NC) and each of the independent factors, for estimation of unadjusted odds ratio (OR). The model estimated unadjusted ORs along with 95% confidence intervals. Once significant factors were identified (presence, severity, and extension of history of periodontal disease),

§ ImageJ, National Institutes of Health, Bethesda, MD.

a multiple logistic regression model was estimated to obtain adjusted ORs and to control possible confounding effects among variables. Level of significance used in analyses was 5% ($\alpha = 0.05$).

A logit model for association between outcome and an independent factor of two levels was conducted, to reach a power of 80% to detect OR = 3.0 as statistically significant, assuming a level of confidence of 95%. Such an OR would be equivalent to proportions of compliance of 25% and 50% in two groups of patients. The highest level of compliance was considered the event whose probability is modeled with the regression.

Accordingly, for a continuous variable (age, mean MBL), OR was interpreted as the amount by which risk of a higher degree of compliance was multiplied when the variable increased one unit (1 mm of MBL). For a categoric factor, OR was interpreted as the amount by which the risk of a higher degree of compliance was multiplied when it was compared with the level of a certain factor with respect to the first (reference factor OR = 1).

For implant-level analysis, a logit model was estimated applying the generalized estimated equations. Dependent variables were the degree of PIMT compliance and peri-implantitis. Effects of possible prognostic factors were evaluated applying χ^2 de Wald at a level of significance of 5% ($\alpha = 0.05$).

RESULTS

Demographics

A total of 153 patients with 241 implants were screened for eligibility. Overall, 206 implants placed in 115 patients, with mean follow-up of 46.85 ± 5.80 months (range: 36 to 55 months), met the inclusion criteria and were clinically and radiographically analyzed. Six implant systems were evaluated.[‖¶#**††‡‡] Of them, 153 were bone-level implants, 28 were tapered-internal implants, and the remaining 25 were tissue-level implants. All implants assessed supported fixed prostheses (146 fixed prostheses and 60 single crowns).

Association Between Compliance and Peri-Implant Diseases at Patient Level

The association between compliance and peri-implant condition was statistically significant ($P = 0.04$). Within RC, although 72.7% were healthy, 4.5% had peri-implantitis. On the contrary, only 53.5% NC, encompassing EC and NC, were healthy, whereas a mean of 23.9% had peri-implantitis (OR = 0.14, $P = 0.01$). In other words, compliance was associated with 86% fewer conditions of peri-implantitis. Similarly, presence of peri-implantitis was significantly less associated with regular compliance (OR = 0.19, $P = 0.10$). On the other hand, mucositis was equal for both groups (OR = 0.74, $P = 0.52$).

Association Between Compliance Degree and Peri-Implant Diseases at Patient Level

Table 1 displays an association between degree of PIMT compliance and independent factors. Findings for the primary objective demonstrated that compliance was significantly associated with peri-implantitis. Prevalence of peri-implantitis was 4.5%, 26.3%, and 14.3% for RC, EC, and NC, respectively, but no association was found either with incidence of mucositis or when RC and EC were compared with NC. Moreover, probability of developing peri-implantitis was substantially associated with reduction in EC compared with RC (OR = 0.13, $P = 0.01$) (Figs. 1A and 1C).

Indicators on Peri-Implant Maintenance Therapy Compliance at Patient Level

It was found that patients with history of periodontal disease had 4.23 times the probability of being EC (versus NC) compared with patients with no history of periodontal disease ($P = 0.02$). As such, 35.7%, 70.2%, and 63.6% were NC, EC, and RC, respectively, with history of periodontal disease. The same trend (OR = 3.15), without reaching significance ($P = 0.07$), was observed for RC (versus NC). Moreover, when comparing RC to EC, it was identified that having a history of moderate periodontal disease was less associated with being fully compliant compared with mild periodontal disease (OR = 0.25, $P = 0.04$). A history of a severe degree of periodontal disease showed less compliance compared with history of mild periodontal disease status (OR = 0.19, $P = 0.07$). Furthermore, the generalized type of periodontal disease was significantly more associated with being RC (versus NC) compared with the localized category of periodontal disease (OR = 18.0, $P = 0.04$). Light smokers resulted in being NC compared with RC (OR = 0.18, $P = 0.04$) and EC (OR = 0.14, $P = 0.02$). It was also found that for each 1-mm increase of MBL, probability of being RC (versus EC) was significantly less (OR = 0.28, $P = 0.001$). Likewise, NC had more MBL compared with RC; however, no statistical significance was found compared with the EC group (OR = 0.34, $P = 0.07$).

Association Between Compliance Degree and Peri-Implant Diseases at Implant Level

Association between compliance and peri-implantitis reached statistical significance ($P = 0.02$). Overall, 78.3% of healthy implants were allocated within RC; however, only 65.9% were observed in NC (EC and

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Table 1.

Association Between Degree of PIMT Compliance and Independent Factors as Result of Applying Simple Binary Logistic Regression Analysis to Calculate ORs

	RC Versus EC		RC Versus NC		EC Versus NC	
Variable	OR	*P* Value	OR	*P* Value	OR	*P* Value
Age	1.01	0.56	0.96	0.20	0.94	0.08
Sex						
Males	1		1		1	
Females	1.85	0.13	2.50	0.17	1.35	0.65
History of periodontal disease						
No	1		1		1	
Yes	0.74	0.49	3.15	0.07	4.23	0.02*
Severity of periodontal disease						
Mild	1		1		1	
Moderate	0.25	0.04*	—	—	—	—
Severe	0.19	0.07	—	—	—	—
Extent of periodontal disease						
L	1		1		1	
G	5.73	0.11	18.0	0.04*	3.14	0.25
Smoking (<10 cig/day)						
No	1		1		1	
Yes	1.32	0.74	0.18	0.04*	0.14	0.02*
MBL (mm)	0.28	0.001†	0.34	0.07	1.42	0.44
Peri-implantitis case definition ≥2 mm MBL						
Healthy	1		1		1	
Mucositis	0.78	0.62	0.63	0.51	0.80	0.75
Peri-implantitis	0.13	0.01†	0.25	0.20	2.00	0.42
Peri-implantitis case definition ≥3 mm MBL						
Healthy	1		1		1	
Mucositis	0.51	0.15	0.42	0.18	0.82	0.74
Peri-implantitis	0.28	0.13	—	—	—	—
Peri-implantitis case definition ≥4 mm MBL						
Healthy	1		1		1	
Mucositis	0.47	0.08	0.50	0.28	1.08	0.90
Peri-implantitis	—	—	—	—	—	—

— = not applicable; L = localized; G = generalized; cig = cigarettes.
* $P < 0.05$.
† $P < 0.01$.

NC). Conversely, frequency of peri-implantitis at implant level was significantly associated with NC (EC and NC) (OR = 0.12, $P = 0.004$). In this sense, implants under strict compliance were highly associated with health (88%). Mucositis, on the contrary, did not reach significance when comparing both groups (OR = 0.95, $P = 0.91$) (Figs. 1B and 1D).

Association Between Compliance Degree and Peri-implant Diseases at Implant Level

Table 2 displays degree of PIMT compliance and independent factors. It was found that, whereas peri-implant mucositis did not seem to be associated with level of compliance, being EC was significantly associated with the condition of peri-implantitis (OR = 0.11; $P = 0.003$). As such, whereas only 2.4% of implants were diagnosed with peri-implantitis in the RC group, 19% and 8.7% belonging to the EC and NC groups, respectively, had peri-implantitis.

Indicators on Peri-Implant Maintenance Therapy Compliance at Implant Level

Similarly, data regarding indicators on PIMT compliance are presented in Table 2. In summary, mean

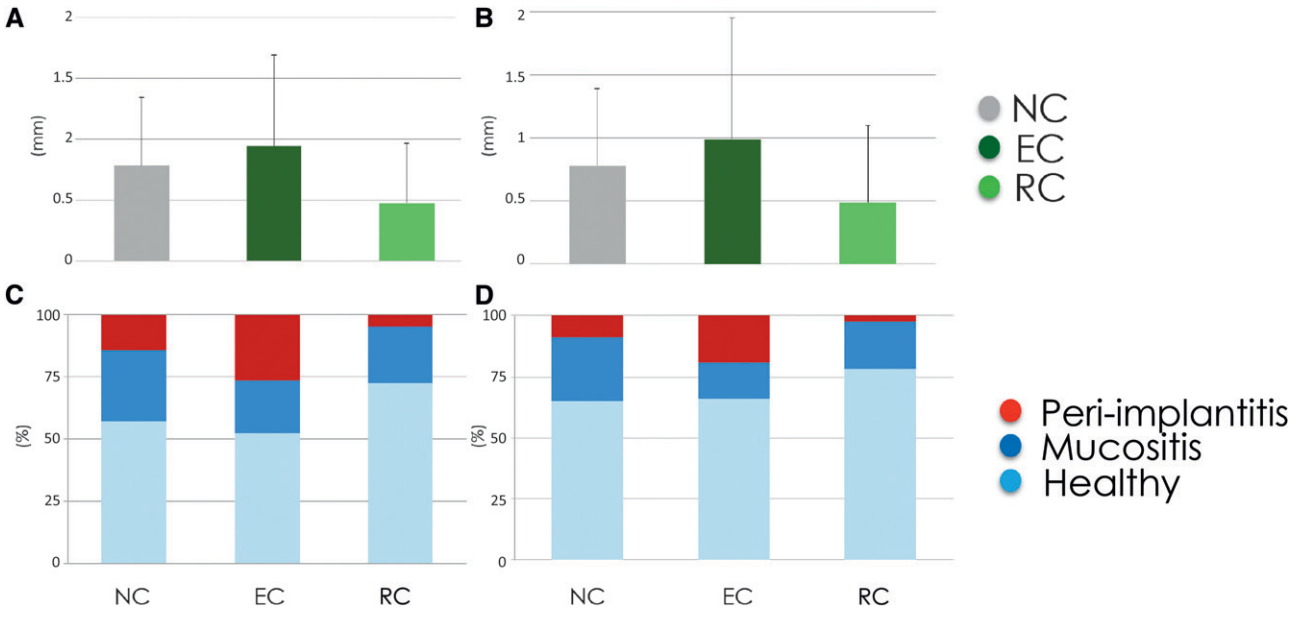

Figure 1.
*Peri-implant radiographic MBL at **(A)** patient level and **(B)** implant level. Peri-implant conditions (%) according to compliance regimen at **(C)** patient level and **(D)** implant level.*

PI was found to be strongly and moderately associated with compliance between RC and EC versus NC (OR = 0.09, $P = 0.002$ and OR = 0.19, $P = 0.04$, respectively). In addition, for each 1-mm MBL increment, the association of being RC (versus EC) was significantly less (OR = 0.42, $P = 0.01$). PD also represented a sensitive indicator for PIMT compliance level. Accordingly, for each 1-mm PD increase, the association of being RC (versus EC) was substantially reduced (OR = 2.73, $P = 0.001$). Statistical significance was further reached when comparing RC versus NC (OR = 2.63, $P = 0.002$). On the other hand, SUP was more sensitive to NC versus EC (OR = 11.6, $P = 0.04$), favoring for EC, whereas no significance was reached when comparing NC versus RC (OR = 6.12, $P = 0.17$).

Clinical Indicators of Peri-Implant Conditions

Mean PI was only sensitive to diagnose peri-implantitis compared with health (OR = 4.48, $P = 0.02$) but not mucositis (OR = 1.39, $P = 0.52$) (Table 3).

Mean BOP was a sensitive parameter to discern mucositis compared with health (OR = 5.42, $P = 0.001$). This was significantly incremental to OR = 15 when peri-implantitis was diagnosed ($P < 0.001$).

Mean PD was sensitive to significantly discriminate among the three groups. Accordingly, likelihood of developing mucositis versus healthy (OR = 1.52; $P = 0.01$), peri-implantitis versus healthy (OR = 2.37; $P < 0.001$), and peri-implantitis versus mucositis (OR = 1.69; $P = 0.03$) resulted statistically significantly to be accurately diagnosed based solely on the PD.

Mean MR was strongly associated with mucositis (OR = 60.9, $P < 0.001$) and peri-implantitis (OR = 16.3, $P < 0.001$) compared with healthy individuals. However, it was lower for peri-implantitis compared with mucositis (OR = 0.22, $P = 0.05$).

Mean SUP was a strongly sensitive value to diagnose peri-implantitis (OR = 20.3, $P < 0.001$) (Fig. 2, Table 3).

DISCUSSION

Main Findings and Agreements/Disagreements With Previous Findings for Primary Outcome

Peri-implant disease, as with periodontal disease, represents a chronic inflammatory entity promoted by microbial biofilm in susceptible hosts. Accordingly, disruption of the assemblage of surface-associated microbial cells enclosed in an extracellular polymeric matrix must be routinely removed through self-performed oral hygiene measures. In addition, professional preventive therapies, including strategies for early diagnosis of pathology and early removal of precipitant irritants, must be adopted to ensure long-term successful outcomes.[23] Based on this, PIMT compliance represents the key to achieving an inflammation-free environment that could achieve harmony between hard and soft tissue stability.[24] For instance, it was demonstrated that dental implant failure rate was reduced by 90% in patients who had regular maintenance versus no maintenance.

Table 2.

Association Between Degree of PIMT Compliance and Independent Factors Analyzed Applying Generalized Estimation Equations for Logistic Simple Binary Logistic Regression Analysis to Calculate ORs

Variable	Condition	RC Versus EC		RC Versus NC		EC Versus NC	
		OR	*P* Value	OR	*P* Value	OR	*P* Value
MBL (mm)		0.42	0.006*	0.51	0.14	1.33	0.28
PI (I/0)		0.39	0.05	0.09	0.002*	0.19	0.04†
BOP (I/0)		0.49	0.14	0.96	0.96	2.02	0.47
PD (mm)		0.95	0.72	2.63	0.002*	2.73	0.001*
MR (I/0)		0.74	0.52	0.74	0.72	1.00	0.99
SUP (I/0)		0.52	0.24	6.12	0.17	11.6	0.04†
Peri-implantitis case definition ≥2 mm MBL	Healthy	1		1		1	
	Mucositis	1.08	0.87	0.62	0.53	0.57	0.45
	Peri-implantitis	0.11	0.003*	0.23	0.14	2.16	0.31
Peri-implantitis case definition ≥3 mm MBL	Healthy	1		1		1	
	Mucositis	0.63	0.31	0.46	0.25	0.73	0.61
	Peri-implantitis	0.29	0.12	—	—	—	—
Peri-implantitis case definition ≥4 mm MBL	Healthy	1		1		1	
	Mucositis	0.58	0.18	0.52	0.31	0.89	0.86
	Peri-implantitis	—	—	—	—	—	—

1 = yes; 0 = no; — = not applicable.
* $P < 0.01$.
† $P < 0.05$.

Additionally, for "patients that had <1 maintenance visit/year, failure rate was reduced by 60% compared with no maintenance."[25] In this respect, it has been reported that patients attending to routine PIMT are significantly less exposed to peri-implant bone loss progression.[12,26] In a comparative 12-month study, it was found that PIMT every 4 months potentially reduces risk of developing peri-implantitis compared with no PIMT (3.7% versus 22.7% at patient level, respectively).[27] Strikingly, a long-term assessment observed 8.5% of peri-implantitis at implant level for patients attending at least twice per year (≤6 months), whereas for those who adhered once per year (>6 months), incidence was slightly higher at 9.3%.[28] Likewise, a recent systematic review highlighted the need of administrating peri-implant maintenance measures at least twice a year to decrease rate of peri-implantitis from 36.5% to 12.5% at patient level.[11] This was further demonstrated in another review paper, where it was concluded that implant therapy can be successfully applied in patients with a diagnosis of periodontitis as long as they regularly attend a proper periodontal maintenance program.[29] In agreement with the aforementioned studies, findings from the present trial demonstrate that NC or EC individuals are substantially more exposed to developing peri-implant diseases because a positive association was found. As such, peri-implantitis was 86% less associated, at patient level, for patients adhering to a well-organized PIMT. Additionally, frequency of peri-implantitis concerning NC reported in the present cohort study agreed with findings published elsewhere.[30] This highlights the importance of supplying proper oral hygiene instruction along with strict enrollment of PIMT regimes according to patient risk profiling.[23,31]

Main Findings and Agreement/Disagreement With Previous Findings for Secondary Outcomes

Patient compliance has been demonstrated to be an essential factor for the prevention of periodontitis[3,4,32,33] and peri-implantitis.[12,34-37] Nevertheless, it seems that because of many practitioners' and patients' misperception and misunderstanding that implants are life-lasting fixtures without need for enrollment in a regular PIMT program,[13] PIMT has not been frequently implemented as part of the treatment plan. Besides, several influencing factors, such as

Table 3.

Association Between Peri-Implantitis (≥2 mm MBL) and Independent Factors Analyzed Applying Generalized Estimation Equations for Logistic Simple Binary Logistic Regression Analysis to Calculate ORs

	M Versus H		P-I Versus H		P-I Versus M	
Variable	OR	*P* Value	OR	*P* Value	OR	*P* Value
Age	1.00	0.95	1.01	0.72	1.01	0.82
Sex						
Males	1		1		1	
Females	1.80	0.20	1.86	0.20	1.03	0.96
History of periodontal disease						
No	1		1		1	
Yes	0.94	0.90	2.03	0.15	2.16	0.23
Severity of periodontal disease						
Mild	1		1		1	
Moderate	0.54	0.34	4.64	0.16	8.66	0.08
Severe	2.22	0.39	6.66	0.10	3.00	0.44
Extent of periodontal disease						
Localized	1		1		1	
Generalized	0.50	0.39	0.55	0.54	1.09	0.91
Implant position						
Mandibular anterior	1		1		1	
Mandibular posterior	0.51	0.23	—	—	—	—
Maxillary anterior	0.63	0.47	—	—	—	—
Maxillary posterior	0.44	0.14	—	—	—	—
Implant system						
**	1		1		1	
‖	1.66	0.54	1.02	0.98	0.62	0.67
§	0.78	0.77	2.75	0.20	3.50	0.22
¶	2.25	0.29	0.500	0.59	0.22	0.24
Implant neck design						
Bone level	1		1		1	
#	0.78	0.74	0.46	0.32	0.59	0.60
Tissue level	2.01	0.18	—	—	—	—
Smoking (<10 cigs/day)						
No	1		1		1	
Yes	0.90	0.93	0.97	0.97	1.08	0.95
Plaque (1/0)	1.39	0.52	4.48	0.024*	3.73	0.14
BOP (1/0)	5.42	0.001†	15.0	<0.001‡	2.81	0.20
PD (mm)	1.52	0.01*	2.37	<0.001‡	1.69	0.03*
MR (1/0)	60.9	<0.001‡	16.3	<0.001‡	0.22	0.05
SUP (1/0)	7.03	0.003†	20.3	<0.001‡	2,48	0.22

M = mucositis; H = healthy; — = not applicable; cig = cigarettes; 1 = yes; 0 = no.
* *P* <0.05.
† *P* <0.01.
‡ *P* <0.001.
§ Nobel Biocare, Kloten, Switzerland.
‖ Mozo Grau Ticare, Valladolid, Spain.
¶ Straumann, Basel, Switzerland.
# LaserLok, Biohorizons, Birmingham, AL.
** Biohorizons.

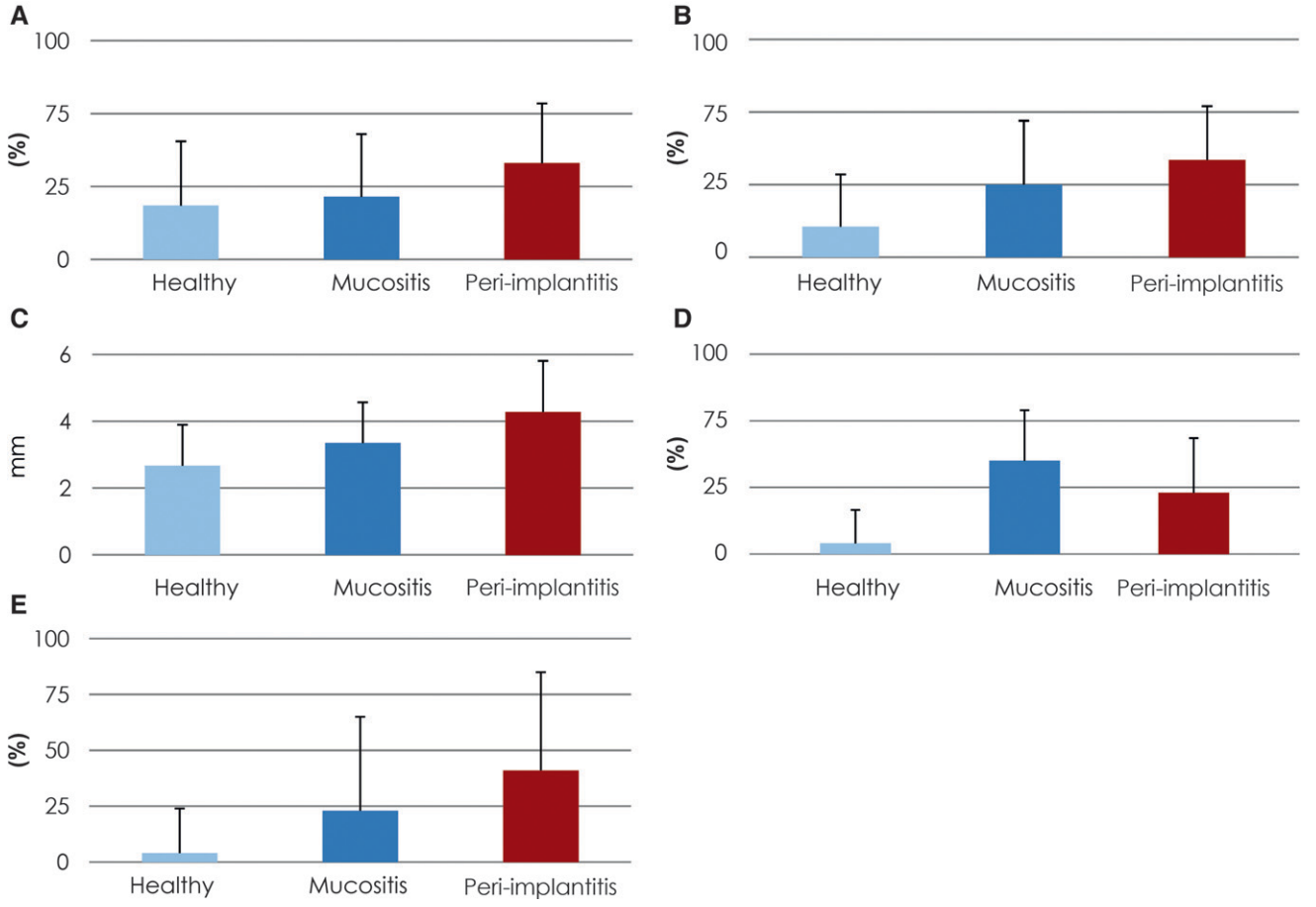

Figure 2.
Peri-implant clinical parameters according to peri-implant conditions. ***A)*** *PI;* ***B)*** *BOP;* ***C)*** *PD;* ***D)*** *MR; and* ***E)*** *SUP.*

geographic distance to the dental practice or conditions such as smoking or DM, have also been associated with erratic compliance.[14]

By any means, patient compliance has been shown to vary widely among different environments. Whereas some studies reported high compliance rates of 77% during 5 years[38] and ≤93% during 10 years,[39] others had found lower rates of ≈30%[40] during 9- to 14-year follow-up. This evidence does not seem to indicate that compliance is higher in implant patients compared with non-implant carriers.[2,33,41,42] Nevertheless, it is worth noting that patient compliance decreases with time,[14] and thereupon, the risk for having peri-implant disease increases. Hence, it is important to emphasize the need to have adequate and regular professional and personal plaque control. This is especially remarkable for patients who had implants for >3 years because greater disease onset is exhibited at this timepoint.[43] The present study is in partial agreement with previous studies according to the case-definition applied for compliance. For instance, in a 3-year follow-up clinical study, Frisch et al.[14] noted compliance of 84%; however, the authors defined compliance as ≥1 visit/year. Therefore, if such a definition is applied to the present data, 87.8% belonged to the RC group, thus agreeing with earlier findings.[14,38,39] Moreover, although without reaching statistical significance, it was elucidated that females and individuals with a history of periodontal disease have a higher trend to comply more regularly. In accordance with a previous report,[14] this could be understood because there is a higher awareness of individuals enrolled in supportive periodontal therapy. Interestingly, the vast majority of these patients were grouped within the EC category. This fact might have led to finding higher peri-implantitis frequency in EC compared with NC by 10% at patient and implant level. In addition, the habit of light smoking (≤10 cigarettes/day) was significantly less associated with RC. This finding was previously reported by Ramseier et al.[44] for patients enrolled in supportive periodontal therapy after periodontal therapy or prophylaxis. This might be explained by the patients' poor regard or belief that their actions/habits impact their

health[45] or it might also reflect patient shame toward not fulfilling the recommendations of smoking cessation.

Into the bargain, as clinical parameters such as PD, BOP, MR, and SUP in the current cohort showed acceptable sensitivity to discern the peri-implant conditions, it is encouraged that the clinician and dental hygienist periodically record and monitor them on a regular basis to assist in early diagnosis of mucositis, where the pathology is yet reversible.[46] These findings are thus consistent with earlier findings in regard to PD and BOP as indicators of peri-implant disease progression[47] and recent studies concerning BOP[48,49] and implant mucosal status.[50]

Limitations and Recommendations for Future Research

Caution must be exercised when interpreting the findings of the present study. First, based on the study design under a cross-sectional basis, a "cause–effect" relationship cannot be drawn, but the "association" between peri-implant conditions and patient compliance could be demonstrated. Moreover, it must be noted that, although the protocols/instructions of both private practices followed the recommendations for periodontal and peri-implant maintenance by the *American Academy of Periodontology* position paper,[17] there might be certain bias elicited. Additionally, when compared with other epidemiologic studies on peri-implant diseases, the case definition must be adequately interpreted. As such, when an alternative case definition was applied (i.e., peri-implant bone loss ≥3 to 4 mm with signs of inflammation), the prevalence of peri-implant diseases dropped substantially for the three groups evaluated, not reaching statistical significance among groups. Hence, it is the current authors' desire to call for future controlled longitudinal studies where the impact of PIMT on peri-implant diseases can be validated applying different case definitions for peri-implantitis.

CONCLUSIONS

Peri-implant maintenance compliance ≥2 PIMT/year seems to be crucial to prevent peri-implantitis in healthy patients. History of periodontal disease and disease severity, as well as its extent and a smoking habit, appear to be factors that influence compliance risk profile. Further long-term studies are warranted to identify different strategies to effectively increase patient adherence to preventive peri-implant maintenance programs.

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