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Long-term results of a three arms prospective cohort study on implants in periodontally compromised patients: 10-year data around sandblasted and acid-etched (SLA) surface

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Abstract

Objectives: The aim of this study was to compare long-term outcomes of sandblasted and acid-etched (SLA) implants in patients previously treated for periodontitis and in periodontally healthy patients (PHP).

Material and methods: One hundred and forty-nine partially edentulous patients were consecutively enrolled in private specialist practice and divided into three groups according to their periodontal condition: PHP, moderately periodontally compromised patients (PCP) and severely PCP. Implants were placed to support fixed prostheses, after successful completion of initial periodontal therapy. At the end of active periodontal treatment (APT), patients were asked to follow an individualized supportive periodontal therapy (SPT) program. Diagnosis and treatment of peri-implant biological complications were performed according to cumulative interceptive supportive therapy (CIST). At 10 years, clinical and radiographic measures were recorded by two calibrated operators, blind to the initial patient classification, on 123 patients, as 26 were lost to follow up. The number of sites treated according to therapy modalities C and D (antibiotics and/or surgery) during the 10 years was registered.

Results: Six implants were removed for biological complications. The implant survival rate was 100% for PHP, 96.9% for moderate PCP and 97.1% for severe PCP. Antibiotic and/or surgical therapy was performed in 18.8% of cases in PHP, in 52.2% of cases in moderate PCP and in 66.7% cases in severe PCP, with a statistically significant differences between PHP and both PCP groups. At 10 years, the percentage of implants, with at least one site

that presented a PD ≥ 6 mm, was, respectively, 0% for PHP, 9.4% for moderate PCP and 10.8% for severe PCP, with a statistically significant difference between PHP and both PCP groups.

Conclusion: This study shows that SLA implants, placed under a strict periodontal control, offer predictable long-term results. Nevertheless, patients with a history of periodontitis, who did not fully adhere to the SPT, presented a statistically significant higher number of sites that required additional surgical and/or antibiotic treatment. Therefore, patients should be informed, from the beginning, of the value of the SPT in enhancing long-term outcomes of implant therapy, particularly those affected by periodontitis.

Introduction

The use of dental implants for replacement of missing teeth has become a routine procedure also in the rehabilitation of the periodontally compromised patients (PCP), even though several studies have identified a high prevalence of peri-implantitis (Berglundh et al. 2002; Fransson et al. 2005; Ferreira et al. 2006; Roos-Jansker et al. 2006; Kolds- land et al. 2010; Simonis et al. 2010; Rinke et al. 2011; Costa et al. 2012; Marrone et al. 2012). In our previous publications (Roccuzzo et al. 2010, 2012), the implant 10-year survival rate varied from 98% in periodontally healthy subjects (PHP) to 90% in severe PCP, even though the lack of adhesion to supportive periodontal therapy (SPT) was associated with a higher incidence of biological complications and a greater need for further therapy. These results were based on the analysis of 112 patients treated, during the years 1996-1999, by means of implants with a coated, titanium plasma-sprayed surface (TPS), which was rather rough and micro- porous and not commercially available nowadays. At the end of the 1990s, implants with the same geometry, but with a sand- blasted and acid-etched (SLA) surface, were introduced to the market to allow loading, in standard bone conditions, after 6 weeks. It seemed natural, at that point, to perpetuate the long-term analysis on another group of patients with a similar protocol, around implants with the new surface.

The aim of this study was to prospectively assess the 10-year results of therapy by means of SLA implants in a group of PHP compared with a group of PCP of both moderate and severe grade. The outcomes regarding implant loss, bone loss, soft tissue recessions, pus, deep pockets, plaque and

bleeding on probing around implants, the additional treatments and number of teeth lost in these patients are described in this article.

Material and methods

Study population

All patients attending the principle investigator (M.R.), a specialist in periodontology, for dental implant therapy between December 1998 and September 2001 were screened for possible inclusion in the study.

Exclusion criteria were:

- complete edentulism;
- presence of an implant-supported overdenture;
- mucosal diseases;
- alcohol and drug abuse;
- pregnancy;
- uncontrolled metabolic disorders;
- aggressive periodontitis;
- no interest in participating in the study.

Patients were informed that their data would be used for statistical analysis and gave their informed consent to the treatment. No ethical committee approval was sought to start this study, as it was not required by national law or by ordinance of the local inspective authority. The prospective study was performed in accordance with the principles stated in the Declaration of Helsinki and the Good Clinical Practice Guidelines.

Pre-treatment clinical examination

Gender, date of birth, smoking habits, medical history at the time of the initial visit and treatment planning were obtained. Moreover, subjects were clinically and radiographically monitored at baseline. Full mouth plaque score (FMPS), full mouth bleeding score (FMBS) and pocket depth (PD) were measured at 4

sites per tooth for all teeth by means of a periodontal probe (XP23/UNC 15, Hu-Friedy, Chicago, USA), and rounded off to the nearest millimeter.

At the baseline, 3 groups were formed on the basis of the clinical diagnosis.

Patient without sign of periodontitis were classified as PHP (periodontally healthy patients). Patient with an initial diagnosis of periodontitis (PCP) received a score (S) on the basis of the number and depth of periodontal pockets according to the following formula:

S = Number of pockets (5-7mm) + 2 Number of pockets ($\geq$8 mm).

These patients were further divided in 2 groups:

- Moderate PCP: periodontally compromised patients with S $\leq$ 25
- Severe PCP: periodontally compromised patients with S > 25.

Periodontal therapy

Following selection, all patients received appropriate initial therapy, consisting, depending on the cases, in motivation, oral hygiene instruction and scaling and root planning. Hopeless teeth were recorded and extracted. Periodontal surgery was performed as needed after re-evaluation. Guided tissue regeneration was pursued, when feasible. Individual treatment was thoroughly discussed with the patients and established according to their personal need and desire. No implant surgery was performed before the assurance of excellent motivation and compliance from each single patient (FMPS≤15%; FMBS≤15%).

Implant placement and prosthetic reconstruction

Sandblasted and acid-etched (SLA) dental implants (Institut Straumann AG, Walden- burg, Switzerland) were placed, under local anesthesia, by the same operator (MR), according to the manufacturer's instructions. Full-body screws

were used, 8, 10 and 12 mm long, 3.3, 4.1 and 4.8 mm in diameter. All implants were placed using a standardized surgical procedure (Buser et al. 2000). The implants were placed with the border of the rough surface approximating the alveolar bone crest leaving the machined neck portion in the transmucosal area. Implants that required bone augmentation and/or sinus lift elevation were not included in the study. If necessary, an excision of soft tissue was performed to allow a close adaptation of the wound margins to the implant shoulder without submerging it. The number, position and type of implants in each patient were determined after a thorough diagnosis of the anticipated needs for the planned prosthesis and the presence of anatomical limitations.

Appropriate healing screws were placed on top of the implants and the flaps were sutured, in a non-submerged fashion. Abutment connection was carried out 6–12 weeks after implant surgery by the same operator. Abutments for cemented restoration were selected according to the intermaxillary space. All patients were provided with implant-supported fixed restorations. All restorations were fabricated to facilitate both the oral hygiene procedures and the probing along their circumference. Baseline probing measurements were also recorded around the implants. Radiographic data were collected, after prosthesis installation, to establish a baseline reference for the following controls.

Follow- up

Patients were placed on an individually tailored maintenance care program (SPT), including continuous evaluation of the occurrence and the risk of disease progression. Motivation, re-instruction, instrumentation and treatment

of re-infected sites were performed as needed. If a patient expressed the desire not to attend follow-up examinations, he/she was classified as “dropout”. The diagnosis and treatment of peri-implant biological complications were performed according to cumulative interceptive supportive therapy (CIST) (Mombelli & Lang 1998), which consists in a series of treatment procedures that have to be cumulative adopted, from A to E, depending on the health conditions of the peri-implant tissues: (A) mechanical cleansing and improvement in patient’s oral hygiene, consisting in removal of hard deposits with soft scalers, polishing with rubber cup and paste. Instruction for more effective oral hygiene practices; (B) antiseptic therapy with chlorhexidine digluconate or local application of chlorhexidine gel; (C) systemic antibiotic therapy or treatment with local delivery device; (D) surgical therapy; and (E) explantation. The number of sites treated according to therapy modalities C and D (antibiotics and/or surgery) during the 10 years was also registered.

Final clinical examination

After 10 years, two calibrated examiners, blinded to the initial classification of the patients, recorded, for each test implant, probing depth (PD) measured at four sites (mesial, buccal, distal and lingual) by means of a periodontal probe (XP23/UNC 15, Hu-Friedy, Chicago, USA), and rounded off to the nearest millimeter.

At the same time the following parameters were collected:

- Implant loss: the time in months for any implant lost;

- plaque score (presence/absence): total score for both teeth and implants (FMPS) and for implants alone (PI), measured at four sites per tooth and implant and expressed as a percentage of examined sites;
- bleeding on probing score (presence/absence): total score for both teeth and implants (FMBS) and for implants alone (BOP), measured at four sites per tooth and implant and expressed as a percentage of examined sites;
- smoking habits;
- number of missing teeth at baseline;
- number of extracted teeth during (APT);
- number of lost teeth during SPT;
- complete adhesion to the SPT (yes or no);
- deepest PD during the SPT;
- deepest PD at 10-year follow-up;
- number of patients, who required, during the SPT, either C or D therapy modality.

Statistical analysis

Data were expressed as mean±SD and median (interquartile range) or counts and percentages.

The statistical distribution of all, except age, quantitative parameters was found to be non-Gaussian (tested by Shapiro–Wilk test), and the significance of between-group differences of the skewed quantitative measures was assessed by generalized linear model (GLM) with gamma parameterization.

Logistic regression models by GLM with logit link and binomial variance function were used to analyze categorical variables.

Because patients received more than one implant, standard errors were all estimated taking account of the correlation of observations. Pairwise comparisons of adjusted predictions between the three groups were performed using Bonferroni's adjustment for multiple comparisons, and a $p < 0.016$ was considered significant. Due to a significant difference between the three groups analyzed, each model was adjusted for patient's age.

All the tests were two-tailed, and statistical significance level was set at 0.05.

Results

Patient population

Of the initial 149 patients enrolled in the study, 26 patients (51 implants) were lost to follow up: 5 died, 3 and 2 patients, respectively, were not able to attend the final examination due to severe health problems or because they moved, and 16 refused the follow-up visit (Table 1).

The final analysis was performed on 123 subjects: 32 PHP, 46 moderate PCP and 45 severe PCP, corresponding to 54,96 and 102 implants, respectively. PHP had a statistically significant lower mean age (43.3 ± 12.4 years) compared with both moderate (53.3 ± 10.7) and severe PCP (52.7 ± 8.4). The mean number of pockets both 5–7 mm and ≥ 8 mm at baseline was statistically significantly different ($p < 0.0001$) between the three groups (Table 2).

Periodontally healthy patients (PHP) had and lost less teeth, at the baseline and during the active therapy, respectively, compared with both PCP groups. The mean number of teeth lost during the SPT was 0.7 ± 1.0 for PHP, 1.3 ± 1.3 for moderate and 1.9 ± 1.9 for severe, respectively, with a significant difference among the three groups ($p < 0.0001$; Table 2).

At baseline, statistically significant differences were found among the three groups regarding both FMPS and FMBS (Table 3). Both parameters increased from PHP (29.0 ± 9.2 and 25.0 ± 11.8) to moderate PCP (37.9 ± 9.3 and 36.9 ± 12.7) up to severe PCP (51.6 ± 22.4 and 48.9 ± 19.4).

At the 10-year examination, both FMPS and FMBS decreased in all groups and the differences between the groups were not statistically significant.

Implant survival rate

In PHP, no implant loss occurred, yielding a survival rate of 100% at 10-year follow-up. Three implants in each PCP group were lost, with a survival rate of 96.9% and 97.1% in moderate PCP and severe PCP, respectively. Considering only the patients who adhered to SPT, the survival rate was 100% for moderate PCP and 98.6% for severe PCP. These values decreased to 93.2% and 93.3% for moderate and severe PCP, who did not fully adhere to SPT. Differences between the groups were not statistically significant (Table 4).

PD and radiographic bone loss

During SPT, 6 implants in PHP, 24 in moderate and 36 in severe PCP presented at least one site with probing depth ≥ 6 mm. The differences were significant between the PHP and both PCP groups (Table 4). No radiographic bone loss ≥ 3 mm was recorded for implants in PHP. On the contrary, 9.4% and 10.8% of the implant surfaces displayed a radiographic bone loss ≥ 3 mm, respectively, in moderate and in severe PCP. The differences between PHP and both PCP groups were statistically significant ($p < 0.001$; Table 4).

Pus and interventions C or D during the SPT

During the 10-year period, pus was detected around 11 of 93 implants in moderate PCP, 8 of 99 implants in severe PCP, while it was never found in PHP. The difference between PHP and both moderate ($p = 0.002$) and severe PCP ($P = 0.01$) was statistically significant (Table 5).

Periodontally healthy patients (PHP) needed in 18.8% of the cases an antibiotic or surgical therapy for the treatment of biological complications (Table 4). The corresponding values for moderate and severe PCP were

52.2% and 66.7%, respectively. The statistical analysis revealed a significant difference between PHP and both PCP groups (PHP vs. moderate PCP: $p = 0.001$; PHP vs. severe PCP: $p < 0.001$).

Clinical parameters at the 10-year follow-up

PIaque around the tested implants was found at the 10-year examination as follows: 19.9 ± 21.9% for PHP, 34.7 ± 33.6% for moderate PCP and 33.3% ± 28.1% for severe PCP, while BoP was found to be 31.9 ± 26.3%, 34.7 ± 33.0% and 38.4 ± 28.6%, respectively (Table 5). A few implants (4 vs. 7 vs. 8) displayed a mucosal recession ≥ 3 mm at the 10-year examination with no significant difference among the groups ($p = 0.99$).

SPT

Thirteen PHP, 21 moderate PCP and 14 severe PCP had an inconsistent attendance to the SPT or refused the proposed additional treatment, during the 10-year period. These subgroups of patients showed worst results in terms of PI, BoP, mean PD, number of teeth lost during SPT, mean deepest PD at the 10-year examination, as well as mean deepest PD registered during the follow-up (Tables 6 and 7).

The differences between patients adhering or not to the SPT were statistically significant in the following cases:

- moderate PCP: PI ($p < 0.001$), BoP ($p = 0.018$), deepest PD at 10-year ($p = 0.02$) and implants with at least one site with PD ≥ 6 mm ($p < 0.001$);
- severe PCP: probing depth ($p = 0.03$), teeth lost during SPT ($p = 0.03$), deepest PD at 10 year ($p = 0.01$) and implants with at least one site with PD ≥ 6 mm ($p = 0.001$).

No significant difference was found among the PHP group.

Patients regularly attending to the SPT received a greater number of C or D interventions during the follow-up compared with the ones who did not. However, these differences were not statistically significant.

Considering FMPS and FMBS, the analysis revealed a trend to higher values, both at baseline and at final examination, for patients inconsistently attending SPT compared with regular attendees. The differences were highly significant for moderate and severe PCP (Table 8).

Discussion

Long-term results of implant therapy in patients with a history of periodontitis have received significant attention in the last years. Since the publication of the second part of the previous study (Roccuzzo et al. 2012), several studies, many of them retrospective or cross-sectional, have been published on this topic.

Rinke et al. (2011) evaluated the prevalence rates of peri-implant mucositis and peri-implantitis in 89 partially edentulous patients in a private practice-based cross-sectional study. In this study, periodontal disease could not be determined as a risk factor for peri- implant mucositis and/or peri-implantitis. In their discussion, the authors tried to explain the reasons why the study failed to determine history of periodontal disease as a risk indicator for peri-implant diseases, as it included only patients with chronic periodontitis. It appears plausible that patients with aggressive periodontitis are likely to exhibit a higher risk of peri-implant diseases. It must be said, however, that an unequivocal distinction between severe and aggressive periodontitis is very difficult in the clinical practice (Picolos et al. 2005), and it is one of the reasons why it was not applied in our protocol. Nevertheless, the authors concluded that smoking and compliance were important risk factors for peri-implant inflammations in partially edentulous patients. These results are in concordance with another recent long-term study (Aglietta et al. 2011). In the present study, the relative number of smokers (21 of 123) was limited and did not allow any statistical analysis.

Around the same time, Levin et al. (2011) published a prospective cohort study consisting of 736 patients (2336 implants) with a follow-up to 144

months (mean 54.4 months). The Kaplan–Meier estimates for the cumulative survival rate (CSR) at 108 months were 0.96 and 0.95 for implants inserted into healthy and moderate PCP, respectively. The CSR declined to 0.88 at 108 months for the severe PCP. The extended Cox model revealed that until around 50 months, periodontal status is not a significant factor but after 50 months, the hazard for implant failure is eight times greater for the severe PCP. These results are in accordance with our previous publications (Roccuzzo et al. 2010, 2012) but they could not be confirmed in this last research. The reason for this is not fully understood. It must be said, however, that both the stricter selection criteria regarding the presence of inflammation and the additional treatment during SPT have significantly reduced the number of implant loss, thus limiting the possibility to determinate the influence of the initial periodontal diagnosis on implant survival.

Ormianer & Patel (2012) have published a retrospective study on the efficacy of dental implant therapy in PCP, monitored annually for at least 9.5 years. They found that periodontal susceptibility resulted in increased bone loss but did not affect implant survival. This is partially in accordance with the results of this study, where no sites presented bone loss ≥ 3 mm in PHP, 9.4% in moderate PCP and 10.8% in severe PCP, with a significant difference among PHP and both PCP groups.

The fact that no radiographic bone loss ≥ 3 mm was recorded for implants in PHP confirms that proper placement in healthy patients, who are enrolled in a proper maintenance program, has an extremely low incidence of biological complications around SLA implants. Similar results were recently published by Buser et al. (2012) who presented a retrospective analysis resulted in a 10-

year implant survival rate of 98.8% and a success rate of 97.0%. In addition, the prevalence of peri-implantitis in this large cohort of orally healthy patients, treated by means of the same implant type, was low with 1.8% during the 10-year period. The possibility to have the same results with other implant types and surfaces cannot be confirmed at the present time. There is the definitive need for long-term prospective observational studies for the different fixtures as results cannot be transferred from one system to another one, as advocated by a recent systematic review (Safii et al. 2010).

There are opinions among clinicians that the prognosis of complex periodontal therapy may not match the high levels of success of treatment with implants. As a consequence, more and more teeth are extracted on the assumptions that implants perform better than periodontally compromised teeth and that their longevity is independent of the individual's susceptibility to periodontitis (Lundgren et al. 2008). In reality, during the 10-year SPT, the mean number of teeth lost per patient, regardless of the clinician providing the service and the reason for the extraction, was 0.7 ± 1.0 for PHP, 1.3 ± 1.3 for moderate PCP and 1.9 ± 1.9 for severe PCP, with a significant difference between PHP and PCP. It is important to note that in relation to the adhesion to the SPT, no difference was found for PHP, a limited, but not significant difference was found in the moderate PCP (1.6 ± 1.4 vs. 1.1 ± 1.2), while a significant difference was found for severe PCP (2.9 ± 2.3 vs. 1.4 ± 1.5). These results confirm that PCP, who are not completely enrolled in an appropriate SPT, tend to have more complications both around implants and teeth and should not be treated on the assumption that the implants perform better than teeth. These conclusions are similar to those reported by Pjetursson et al. (2012) in

70 patients with a follow-up ranging from 3 to 23 years (mean 7.9 years). After installation of the implants, 58 patients entered a university SPT program and 12 had SPT in a private practice. The authors reported that the prevalence of peri-implantitis was lower in the group followed in a well-organized SPT at the university. The present paper, on the contrary, presents excellent results in terms of overall compliance even for patients in a private office.

Mir-Mari et al. (2012) estimated the prevalence of peri-implantitis in private practice patients, enrolled in a periodontal maintenance program, between 12% and 22%, similarly to those published in university environment samples. Nevertheless, it must be stressed, once again, the importance of SPT regardless of the fact that it takes place in a public or private base. In the present study, 26 of 149 (17.4%) patients were lost to follow up and only 16 of these (10.7%) refused the visit for various personal reasons. These values should be considered positively in consideration of the long period of the follow-up, and they are somehow similar to those published in a recent paper reporting results in a private practice by Cardaropoli & Gaveglio (2012).

The overall quality of the SPT in the present research can be confirmed by the significant reduction in the FMPS and FMBS values at the 10-year follow-up. These changes are more pronounced in patients adhering to SPT comparing to the ones not adhering to SPT. Indeed, patients undergoing a successful SPT should have similar low plaque scores regardless of the history for periodontitis. In this group of patients, the FMPS, at the 10- year evaluation, before the session of scaling, was below the 25% threshold, that is, respectively, 19.0 ± 10.4% vs. 23.4 ± 15.3% vs. 22.9 ± 14.4%, with no difference among the groups.

The number of implants with a PD≥ 6 mm varied among the three groups, with differences that were statistically significant (Table 4). Our data support the need for a SPT where clinical and, when indicated, radiographic parameters should be re-assessed at every follow-up visit to detect peri-implant infections as earlier as possible and to intercept the problems with appropriate therapy (Mombelli & Lang 1998).

During the entire period of observation, six implants were removed for biological complications in PCP. It must be noted that these results are better than those published in a different group of patients treated with TPS implants (Roccuzzo et al. 2010, 2012). While the TPS surface has S_a values of approximately 3.1 lm, SLA has S_a values of approximately 2.0 lm (Buser et al. 1999). The lower microroughness should be particularly important in PCP, because it is suggested that peri-implantitis is influenced by surface characteristics (Berglundh et al. 2007; Albouy et al. 2008, 2009). However, caution is needed comparing the present study with the previous ones (Roccuzzo et al. 2010, 2012), because of stricter plaque regimen entry level (FMPS ≤ 15% vs. FMPS ≤ 25%).

The results of the present investigation do not confirm the observation by Charalampakis et al. (2012) who found, in a retrospective study, that SLA was statistically significantly associated with peri-implantitis, while TPS was not. It must be said, however, that in a recent systematic review, prepared for the Seventh European Workshop on Periodontology, Renvert et al. (2011) revealed that only few studies provided data on how implant surfaces influence peri-implant disease, with no evidence that implant surface characteristics can have a significant effect on the initiation of peri-implantitis.

There is no reason to assume that the shorter waiting time between surgery and loading in this group of patients (6–12 weeks) compared with the previous one (3–6 months) (Roccuzzo et al. 2010) had any significant effect of the overall results, but this cannot be confirmed.

Finally, antibiotic and/or surgical therapy was performed in 18.8% of cases in PHP, in 52.2% of cases in moderate PCP and in 66.7% cases in severe PCP. In other words, in order to have a very elevated long-term survival rate, it is mandatory to monitor patients frequently, especially those who lost teeth due to periodontal disease, to organize and to promptly carry out adjunctive additional treatment, as needed. Therefore, implant therapy cannot be simply proposed as “definitive”, but it should be considered only as an important step in the comprehensive long-term treatment plan of patients.

In conclusion:

- Overall, proper therapy by means of SLA implants, supporting both single crowns and fixed dental prostheses, offers predictable long-term results.
- In particular, healthy patients who are enrolled in a proper maintenance program have an extremely low incidence of biological complications.
- Patients with a history of periodontitis should be informed that they are at higher risk of peri-implant disease.
- Excellent values of long-term survival rate can be obtained even in PCP, if these are placed on an individually tailored maintenance care program, including continuous evaluation of the occurrence and the risk of disease progression.
- PCP, even though achieved optimal plaque control, may need further

therapy to limit the nature and extent of biological complications throughout time.

- Biological complications, detected at an early stage, can be successfully treated by means of antibiotics and/or regenerative surgery in a high percentage of cases.
- Regardless of their initial status, patients may experience peri-implant soft tissue dehiscence, which may cause esthetic problems.

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Table 1. Number of patients and implants lost to the 10-year follow-up.

	Patients	Implants	Reason for drop-out
	5	13	Death
	3	8	Severe health problems
	2	3	Moved
	16	27	Refused to accept a visit
Total	**26**	**51**	

Table 2. Study population: total number of patients attending the 10-year examination, mean age and number of smokers. Mean number of teeth missing at baseline, extracted during Active Periodontal Therapy (APT) and during SPT.

	Patients at the 10-year examination	Mean age (years)	Smokers	Number of pockets 5-7 mm	Number of pockets ≥ 8 mm	Teeth missing at baseline	Teeth extracted during APT	Teeth lost during SPT
PHP	32	43.3 ± 12.4	5	0.9 ± 1.0 1 (0-1.5)	0 0 (-)	3.2 ± 3.1 2 (1-4.5)	1.3 ± 1.2 1 (1-2)	0.7 ± 1.0 0 (0-1)
Moderate PCP	46	53.3 ± 10.7	6	7.5 ± 3.4 7 (6-8)	2.7 ± 1.9 2.5 (1-4)	7.1 ± 4.6 7 (3-10)	2.3 ± 1.9 2 (1-3)	1.3 ± 1.3 1 (0-2)
Severe PCP	45	52.7 ± 8.4	10	23.3 ± 10.0 21 (15-27)	8.6 ± 5.9 7 (5-10)	5.6 ± 3.8 5 (2-8)	3.5 ± 2.8 3 (1-4)	1.9 ± 1.9 1 (1-3)
Statistical difference between:								
All groups			*p = 0.49*			*p=0.05*	*p<0.02*	
PHP and moderate PCP		*p < 0.0001*		*p < 0.0001*	*p < 0.0001*			*p < 0.0001*
PHP and severe PCP		*p = 0.01*		*p < 0.0001*	*p < 0.0001*			*p < 0.0001*
Moderate PCP and severe PCP		*p = 0.99*		*p < 0.0001*	*p < 0.0001*			*p < 0.0001*

Table 3. Patients' compliance and clinical parameters (Full-mouth plaque score [FMPS] and full-mouth bleeding score [FMBS]) at baseline and at the 10-year follow-up.

	Patients at the 10-year examination	Patients adhering / not adhering to SPT	FMPS baseline	FMBS baseline	FMPS at 10-year follow-up	FMBS at 10-year follow-up
PHP	32	19 / 13	29.0 ± 9.2 30 (22-34)	25.0 ± 11.8 25 (18-30)	22.1 ± 10.8 22 (13-30)	18.4 ± 12.6 15 (10-25)
Moderate PCP	46	25 / 21	37.9 ± 9.3 35 (30-45)	36.9 ± 12.7 33 (28-45)	27.7 ± 14.8 25 (16-33)	25.2 ± 13.0 23 (16-32)
Severe PCP	45	31 / 14	51.6 ± 22.4 45 (35-70)	48.9 ± 19.4 45 (35-60)	30.4 ± 20.6 25 (15-38)	27.4 ± 19.0 22 (19-32)
Statistical difference between: All groups PHP and moderate PCP PHP and severe PCP Moderate PCP and severe PCP		*p = 0.36*	 *p = 0.001* *p < 0.0001* *p < 0.0001*	 *p =0.001* *p < 0.0001* *p = 0.001*	*p=0.22*	*p=0.02*

Table 4. Implants placed, implants lost, survival rates, number of implants with deepest PD ≥ 6mm, percentage of sites with bone loss ≥ 3 mm and percentage of patients treated with cumulative interceptive supportive therapy (CIST) C/D, during the 10-year supportive periodontal therapy (SPT)

	Implants placed	Implants lost	Survival Rate (%)			Implants with deepest PD ≥ 6mm	Radiographic bone loss ≥ 3 mm (%)	Patients treated with CIST C/D (%)
			All patients	Patients adhering to SPT	Patients not adhering to SPT			
PHP	54	0	100	100	100	6	0	18.8
Moderate PCP	96	3	96.9	100	93.2	24	9.4	52.2
Severe PCP	102	3	97.1	98.6	93.3	36	10.8	66.7
Statistical difference between:								
All groups			*p = 0.65*	*p = 0.95*	*p = 0.62*		*p <0.001*	
PHP and moderate PCP						*p = 0.015*	*p<0.001*	*p = 0.001*
PHP and severe PCP						*p <0.001*	*p<0.001*	*p < 0.001*
Moderate PCP and severe PCP						*p = 0.65*	*p=0.97*	*p = 0.95*

Table 5. PI and BoP around the implants at the 10-year examination.

	Patients at the 10-year examination	Implants available at 10y	PI around implants (%)	BoP around implants (%)	Implants with pus during SPT	Deepest PD (mm) during SPT	Implants with REC ≥3mm during SPT
PHP	32	54	19.9 ± 21.9 25 (0-25)	31.9 ± 26.3 25 (0-50)	0	4.4 ± 1.1 4 (4-5)	4
Moderate PCP	46	93	34.7 ± 33.6 25 (0-50)	34.7 ± 33.0 25 (0-50)	11	4.6 ± 1.3 4(4-5)	7
Severe PCP	45	99	33.3 ± 28.1 25 (0-50)	38.4 ± 28.6 25 (0-50)	8	4.8 ± 1.4 4 (4-5)	8
Statistical difference between: All groups PHP and moderate PCP PHP and severe PCP Moderate PCP and severe PCP			*p=0.05*	*p=0.49*	*p = 0.002* *p = 0.01* *p = 0.98*	*p = 0.16*	*p = 0.99*

Number of implants with pus, deepest PD and number of implants with mucosal recession (REC) ≥ 3 mm during the supportive periodontal therapy (SPT)

Table 6. Clinical parameters around the implants at the 10-year follow-up in relation to adhesion to supportive periodontal therapy (SPT) in the three groups.

	Adhesion to SPT	Number of patients	PI (%)	BOP (%)	PD (mm)	Teeth lost during SPT
PHP	No	13	22.7 ± 24.3 25 (0-25)	38.7 ± 31.6 37 (0-35)	3.7 ± 0.8 4 (3.5-4.3)	0.7 ± 1.2 0 (0-1)
	Yes	19	18.0 ± 20.0 25 (0-25)	27.3 ± 21.4 25 (0-50)	3.4 ± 0.6 3.3 (3-3.8)	0.7 ± 0.9 0 (0-1)
p-value			*p = 0.54*	*p = 0.21*	*p = 0.22*	*p = 0.98*
Moderate PCP	No	21	50.6 ± 31.9 50 (25-75)	47.0 ± 36.3 50 (25-75)	4.2 ± 1.3 4 (3-5)	1.6 ± 1.4 1 (0-3)
	Yes	25	22.1 ± 29.6 0 (0-25)	25.0 ± 26.7 25 (0-50)	3.4 ± 0.8 3.3 (2.7-4.1)	1.1 ± 1.2 1 (0-2)
p-value			*p < 0.001*	*p = 0.018*	*p = 0.05*	*p = 0.47*
Severe PCP	No	14	44.6 ± 30.7 50 (25-50)	46.4 ± 30.2 50 (25-75)	4.4 ± 1.1 4.4 (4-5.2)	2.9 ± 2.3 2.5 (1-4)
	Yes	31	28.9 ± 25.9 25 (0-50)	35.2 ± 27.6 25 (25-50)	3.8 ± 0.9 3.6 (3.3-4.3)	1.4 ± 1.5 1 (0-2)
p-value			*p = 0.06*	*p = 0.12*	*p = 0.03*	*p = 0.03*

Pl, presence of dental plaque; BoP,bleeding on probing; PD, probing depth

Table 7. Number of patients treated with cumulative interceptive supportive therapy (CIST) C/D, deepest PD around implants and percentage of implants with deepest PD ≥ 6mm in relation to adhesion to supportive periodontal therapy (SPT) in the three groups.

	Adhesion to SPT	Number of patients	N. of patients treated with CIST C/D	Mean deepest PD at 10–year (mm)	Implants with at least a site with PD≥6mm at 10-year
PHP	No	13	2	4.8 ± 1.3 5 (4-5)	4 / 22
	Yes	19	4	4.2 ± 0.9 4 (4-5)	2 / 32
p-value			*p = 0.99*	*p = 0.25*	*p = 0.21*
Moderate PCP	No	21	11	5.1 ± 1.4 5 (4-6)	20 / 44
	Yes	25	13	4.2 ± 1.1 4 (3-5)	4 / 52
p-value			*p = 0.98*	*p = 0.02*	*p < 0.001*
Severe PCP	No	14	10	5.4 ± 1.5 6 (4-6)	18 / 30
	Yes	31	20	4.6 ± 1.3 5 (4-5)	18 / 72
p-value			*p = 0.65*	*p = 0.01*	*p = 0.001*

Table 8. Full-mouth plaque score (FMPS) and full-mouth bleeding score (FMBS) at baseline and at follow-up in patients adhering and not adhering to supportive periodontal therapy (SPT).

	Adhesion to SPT	Number of patients	FMPS baseline	FMBS baseline	FMPS at 10-year follow-up	FMBS at 10-year follow-up
PHP	No	13	31.1 ± 10.3 30 (29-40)	27.5 ± 15.2 25 (18-35)	26.5 ± 10.2 25 (22-30)	22.2 ±14.8 20 (15-26)
	Yes	19	27.6 ± 8.3 29 (20-33)	23.4 ± 8.8 25 (18-28)	19.0 ± 10.4 15 (10-25)	15.8 ± 10.5 12 (8-22)
p-value			*p = 0.23*	*p = 0.26*	*p = 0.04*	*p = 0.30*
Moderate PCP	No	21	42.6 ± 8.9 44 (35-45)	44.5 ± 12.9 40 (35-50)	32.7 ± 12.8 30 (25-40)	31.2 ± 13.1 30 (20-36)
	Yes	25	34.0 ± 7.7 33 (30-36)	30.4 ± 8.3 30 (26-32)	23.4 ± 15.3 20 (12-30)	20.1 ± 10.8 20 (12-25)
p-value			*p < 0.0001*	*p < 0.0001*	*p = 0.005*	*p = 0.001*
Severe PCP	No	14	60.7 ± 18.1 66 (45-77)	56.2 ± 18.0 57 (45-60)	46.9 ± 23.2 44 (30-55)	43.2 ± 25.6 41 (22-50)
	Yes	31	47.4 ± 23.1 42 (33-70)	45.6 ± 19.4 40 (30-61)	22.9 ± 14.4 20 (15-28)	20.3 ± 8.6 20 (15-25)
p-value			*p = 0.01*	*p = 0.04*	*p = 0.001*	*p = 0.001*