

A retrospective cohort study of peri-implant condition in Chinese patients with different periodontal condition and maintenance frequency

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Abstract

Objectives: To compare the periodontal and peri-implant conditions of Chinese patients with a history of moderate or severe periodontitis and periodontally healthy patients (PHP); to evaluate the influence of maintenance therapy frequency on the outcome of implant therapy.

Methods: A total of 140 participants with 227 sand-blasted acidetched (SLA) implants were divided into three groups: PHP, moderate periodontally compromised patients (PCP) and severe PCP. The three groups were further categorized into two groups based on the frequency of maintenance (MF): MF \geq 1 per year and MF < 1 per year. The following clinical parameters of implants were assessed: implant survival/loss, peri-implant probing depth (PDi), peri-implant bleeding index (Bli), peri-implant bleeding on probing (BOPi), implant bone loss (BLi). Comparisons of the peri-implant conditions were performed between the patients with different periodontal conditions.

Results: Implant survival rate was 100% for all three groups. The severe PCP group showed significantly higher deepest PDi, mean PDi, mean Bli, and PLli compared with PHP ($p < 0.05$). The severe PCP group had more implants affected with PDi \geq 5 mm and BOPi+ compared with the PHP group (Adjusted OR = 10.89, 95% CI: 2.34, 50.74). In the patients with severe PCP, the MF < 1 per year group had a greater prevalence of PDi \geq 5 mm and BOPi+ compared with the MF \geq 1 per year group (Adjusted OR = 8.23, 95% CI: 2.44, 27.78).

Conclusions: The patients in the severe PCP group were at greater risk of peri-implant disease than those in the PHP group. In particular, severe PCP who had poor adherence to maintenance care showed a higher incidence of biologic complications.

KEYWORDS

maintenance, peri-implant disease, periodontitis, risk factor

1 | INTRODUCTION

Along with the development of oral rehabilitation of partially or totally edentulous patients with dental implants, implant placement

in patients with a history of treated periodontitis became more widely used, with the implant survival rate is up to 90% over a period of 3–16 years (Heitz-Mayfield & Huynh-Ba, 2009). However, a number of previous studies have demonstrated that a previous

history of periodontitis is the critical determinant of increased risk of peri-implantitis (Karoussis et al., 2003; Pesce et al., 2014; Renvert & Persson, 2009; Simonis, Dufour, & Tenenbaum, 2010; Sousa et al., 2016). There is a trend that the incidence of peri-implantitis is higher and the long-term success rate is lower in patients treated for periodontitis.

Besides a history of periodontitis, substantial scientific evidence has showed that a lack of regular periodontal and implant maintenance treatment is associated with peri-implant diseases (Hultin, Komiyama, & Klinge, 2007; Monje et al., 2016; Rocuzzo, Aglietta, Bunino, & Bonino, 2010; Rocuzzo, Bonino, Aglietta, & Dalmaso, 2012; Rocuzzo, Bonino, Dalmaso, & Aglietta, 2014). A previous systematic review (Monje et al., 2016) aimed at assessing the impact of maintenance therapy on the incidence of peri-implant diseases claimed a minimum recall maintenance therapy interval of 5–6 months. However, documents based on the appropriate intervention recalls according to the different periodontal condition are limited.

Moreover, it is noteworthy that the previous research findings were mostly based on people in developed countries, while the periodontal conditions in Chinese population are obviously different because of the distinct ethnic origin, national conditions, and social environmental factors. According to the results of the third national oral health epidemiological investigation in China, the prevalence of periodontitis is 38.9% in 35 ~ 44-year-old residents and 71.3% in 65 ~ 74-year-old residents (Qi, 2008). In addition, the periodontal treatment rate and maintenance rate is fairly low. Even after periodontal therapy and implant therapy, the periodontal and peri-implant maintenance may still be neglected. Whereas, the use of dental implant to replace missing teeth has become increasingly popular in China. It makes the clinical outcomes of implant therapy for PCP unpredictable. To the best of our knowledge, however, there is a lack of longitudinal studies for evaluating the clinical outcomes of implant treatment in Chinese patients with different periodontal conditions and maintenance therapy frequency.

Therefore, the aim of this retrospective cohort study was to investigate the influence of initial periodontal status and maintenance therapy frequency on the outcome of implant therapy of Chinese patients.

2 | MATERIALS AND METHODS

2.1 | Patient selection

Patients for this retrospective cohort study were recruited from Department of Periodontology, Peking University, School and Hospital of Stomatology. A total of 186 consecutive partially edentulous patients, who had received Straumann® implants (Institute Straumann AG, CH-4437, Waldenburg, Switzerland) by three experienced periodontists during the period between September 2009 and January 2013, were contacted by telephone calls. Eventually, 175 patients were selected. The inclusion criteria were the following: a minimum 1-year follow-up period after implant loading; complete

medical records; patients who had not been diagnosed with uncontrolled diabetes mellitus.

Of all the 175 patients, 140 (80.0%) participated in the study. A total of 7 (4.0%) patients were not reachable. A total of 28 (16.0%) patients refused to participate for various reasons such as busy working schedule or moving to another city. The study protocol was approved by the Ethics Committee of the Peking University Health and Science Center (approval number: IRB00001052-10047). Written informed consent form was obtained from each patient included in the study.

2.2 | Periodontal therapy

The periodontal condition was assessed for all patients and recorded at the initial examination (T1) after supragingival scaling for patients with periodontitis. In total, 106 out of 140 patients had been diagnosed with periodontitis and then were treated with non-surgical and/or surgical periodontal therapy. According to the medical records of the participants before implant surgery, implants were placed in periodontally compromised patients (PCP) only when all active periodontal therapies were completed and had proceeded to the maintenance phase of treatment (no sites with probing pocket depth [PPD] ≥ 6 mm, full-mouth bleeding scores [FMBS] $\leq 25\%$).

2.3 | Implant therapy

The implants were all sand-blasted acidetched (SLA) surfaces (tissue-level or bone-level type). All implants were placed according to the manufacturer's recommended protocols. The timing for implant placement followed a delayed protocol. All patients were partially dentate, and the implant-supported reconstructions included single crowns, fixed partial dentures, or overdentures. The healing period prior to restoration of the implants was between 3 and 6 months after placement.

2.4 | Baseline measurements

General health status, smoking habits, and baseline periodontal charts from the initial periodontal examination (T1) were collected and examined. The full-mouth periodontal examination evaluated the PPD, bleeding index (BI; Mazza, Newman, & Sims, 1981), FMBS, (PPD ≥ 5 mm)%, and (PPD ≥ 6 mm)%. BI was scored at two sites for each tooth (buccal, lingual/palatal) and PPD was scored at six sites (Mesiobuccal, buccal, distobuccal, distolingual, lingual, and mesiolingual). (PPD ≥ 5 mm)% and (PPD ≥ 6 mm)% were the percent of sites with PPD of 5 mm or more and of 6 mm or more, respectively. The subjects were divided into three groups based on the initial periodontal examination (T1): (a) periodontally healthy patients (PHP): patients not susceptible to periodontal pathology; (b) Moderate PCP: periodontally compromised patients who were diagnosed as periodontitis and presented $\leq 30\%$ tooth sites with PPD ≥ 5 mm or $\leq 10\%$ sites with PPD ≥ 6 mm; (c) Severe PCP: periodontally compromised patients who were diagnosed as

periodontitis and presented >30% tooth sites with PPD \geq 5 mm and >10% sites with PPD \geq 6 mm. Intra-oral radiographs were also obtained from the patient records from the time of implant placement and also after placement of the restoration.

2.5 | Follow-up evaluation

The participants were recalled in this study and the follow-up examination (T2) was taken at the final visit. During T2, the information of home oral hygiene practice and frequency of periodontal maintenance of the subjects were collected at chair side. The three groups were further subdivided into two groups based on the frequency of maintenance therapy. "maintenance frequency (MF) \geq 1 per year" group with a mean maintenance therapy interval of less than one year and "MF < 1 per year" group with a mean maintenance therapy interval of more than 1 year. The same full periodontal chart as T1 was completed for each patient. The following clinical parameters of implants were assessed:

1. implant survive/loss;
2. peri-implant probing depth (PDi): probing depth measurements were taken at six sites (Mesiobuccal, buccal, distobuccal, distolingual, lingual, and mesiolingual) per implant;
3. peri-implant bleeding index (Bli) and peri-implant bleeding on probing (BOPi): The Bli used in this study was Mazza Bleeding Index (Mazza et al., 1981; including six grades from 0 to 5) which can provide more detailed gingival condition. Bli \geq 2 was also recorded as "BOPi positive" which was used as a diagnostic indicator of peri-implant disease. The Bli and BOPi were assessed with the most severe sites of the three buccal and lingual/palatal probing sites for each implant, respectively;
4. modified implant plaque index (PLIi): PLIi was recorded as proposed by Mombelli, van Oosten, Schurch, and Lang (1987) and scored at two sites for each implant (buccal, lingual/palatal).

Frequency of implant with PDi \geq 5 mm and BOPi positive ((PDi \geq 5 mm & BOPi+)%) was obtained.

Standardized intra-oral periapical radiographs of implants were taken at the re-evaluation visit for each implant examined for comparison with radiographs taken after placement of the restoration. The distance between the implant shoulder and the first bone-to-implant contact (DIB) on the mesial and distal aspect of each implant were measured to evaluate the implant bone loss (BLi) using software programs (VixWin Platinum Imaging Software[®], Gendex, Des Plaines, IL, USA & Geometer's Sketchpad 5[®], Key Curriculum Press, USA; Figure 1). The diameter of implant shoulder (A-B) was used as a known dimension for calibrating the images and thus compensating for anatomic magnification and distortions in the X-rays. All the follow-up evaluation and radiographic measurements were conducted by a single examiner. Radiographic measurements were taken on two different time points and mean values were then calculated. The intra-observer test-retest reliability was good, as the intraclass correlation coefficient was 0.83.

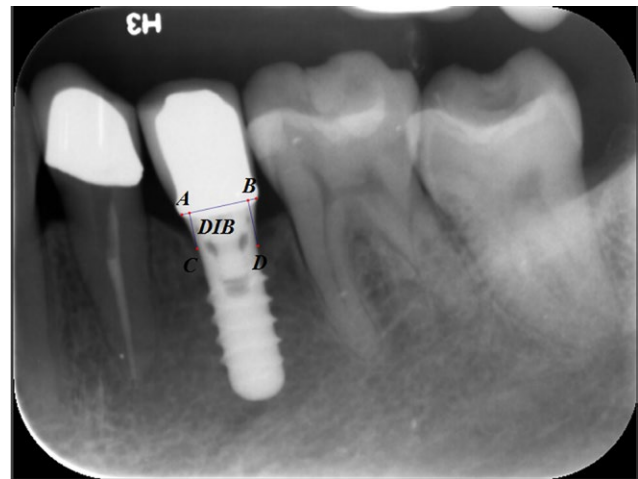


FIGURE 1 Landmarkers used for the radiographic measurements. A-B: the diameter of implant shoulder; C, D: the first bone-to-implant contact; DIB: the distance between the implant shoulder and the first bone-to-implant contact

Peri-implantitis was diagnosed when PDi \geq 5 mm with BOPi positive and BLi \geq 3 mm at the same time. Percentages of implant with peri-implantitis were assessed.

2.6 | Statistical analysis

All statistical analyses were performed with SPSS 19.0 (SPSS Inc., Chicago, IL, USA) software.

Data were expressed as mean \pm SD, median (Q1–Q3) or N (%). The heterogeneity among PHP, moderate PCP, and severe PCP groups with respect to age, gender, and smoking habits was assessed using the Kruskal–Wallis or chi-square test. Comparisons of the periodontal parameters between moderate PCP and severe PCP at T1 were assessed by Mann–Whitney *U* test (non-normally distributed variables including (PPD \geq 5 mm)%, (PPD \geq 6 mm)% and mean BI) and independent *t* test (normally distributed variables including mean PPD and FMBS). Pairwise comparisons of the periodontal parameters between T1 and T2 were assessed by Wilcoxon signed rank test ((PPD \geq 5 mm)%, (PPD \geq 6 mm)% and mean BI) and paired *t* test (mean PPD and FMBS). We performed generalized estimate equation (GEE) to compare the peri-implant parameters in different groups by two models (linear regression model for continuous variables and logistic regression model for categorical variable) with adjusting for confounding variables. A *p* value of <0.05 was considered to indicate a statistically significant difference.

3 | RESULTS

Eventually, 140 subjects were recruited into the study, 73 males and 67 females, with a mean age of 44.6 years (SD = 11.1, range 19–73 years). About 82.9% of the subjects were non-smokers, 7.1% were former smokers, and 10% were current smokers. A total

TABLE 1 Patients demographics

	Number of patients	Number of implants	Follow-up period (months)	Mean age (years)	Gender (male/female)	Smoking (Yes/No)
PHP	34	42	31.4 ± 12.2	36.6 ± 9.1*	8/26*	2/32
ModeratePCP	55	86	25.9 ± 14.5	46.6 ± 11.2	31/24	3/52
SeverePCP	51	99	23.5 ± 12.1	47.7 ± 9.7	34/17	9/42

*Statistically significant difference between PHP and moderate PCP group and between PHP and severe PCP group ($p < 0.05$).

of 227 implants were included, with a mean follow-up period after implant loading of 25.9 months ($SD = 13.3$, range 12–69 months). About 47.1% of the implants had been in function for more than 2 years.

There were 34 subjects with 42 implants in the PHP group, 55 subjects with 86 implants in the Moderate PCP group, 51 subjects with 99 implants in the Severe PCP group, respectively. The patient demographic data are presented in Table 1. There were no statistically significant differences between the two groups with respect to follow-up period or smoking history. However, a lower mean age and a low ratio of man to female were observed in the PHP group compared with moderate PCP and severe PCP groups ($p < 0.05$). The implant distribution and characteristics are described in Tables 2 and 3. A greater proportion of implants in the anterior mandible and a less proportion in the posterior mandible were observed in the severe PCP group. The vast majority of implants were tissue level, accounting for 200 of the 227 implants (88%), while the number of bone-level implant was only 27. The periodontal parameters of the three groups at the initial examination (T1) and follow-up evaluation (T2) are listed in Table 4. At T1, the mean PPD, mean BI, FMBS, PPD ≥ 6 mm%, and PPD ≥ 5 mm% were significantly higher in the severe PCP group compared with the moderate PCP ($p < 0.05$). The mean PPD, mean BI, FMBS, PPD ≥ 6 mm%, and PPD ≥ 5 mm% of moderate and severe PCP groups were significantly decreased at T2 compared with T1 ($p < 0.05$).

Implant survival rate was 100% for all three groups. The severe PCP group showed significantly higher deepest PDi ($\beta = 0.71$, 95%CI: 0.40, 1.03), mean PDi ($\beta = 0.57$, 95% CI: 0.33, 0.81), mean Bli ($\beta = 0.71$, 95% CI: 0.30, 1.13), and PLli ($\beta = 0.32$, 95% CI: 0.12, 0.51) compared with PHP after adjusting for the confounding variables (Table 5). The severe PCP group had 21 implants (21.2%) affected with PDi ≥ 5 mm and BOPI+ compared with three implants (7.1%) in the PHP group, which was statistically significant (Adjusted OR = 10.89, 95% CI: 2.34, 50.74; Table 5). Moreover, there was only one implant in the severe PCP group affected with peri-implantitis at T2 because of the failure of guided bone regeneration.

In patients with severe PCP, MF < 1 /year group had significantly higher deepest PDi ($\beta = 0.71$, 95%CI: 0.30, 1.13), mean PDi ($\beta = 0.58$, 95% CI: 0.32, 0.85), mean Bli ($\beta = 0.74$, 95% CI: 0.33, 1.15), and PLli ($\beta = 0.44$, 95% CI: 0.15, 0.73) than MF ≥ 1 /year group after adjusting for the confounding variables (Table 6). In the patients with severe PCP, the MF < 1 per year group had more implants affected with PDi ≥ 5 mm and BOPI+ compared with the MF ≥ 1 per year group (Adjusted OR = 8.23, 95% CI: 2.44, 27.78; Table 6). The deepest PDi, mean PDi, Bli, PLli, and prevalence of PDi ≥ 5 mm with BOPI+ were slightly but not significantly higher in the MF < 1 /year group than the MF ≥ 1 /year group in patients with PHP or moderate PCP.

TABLE 2 Distribution of implants in posterior and anterior sites

	Number of implants	Ant. maxilla	Post. maxilla	Ant. mandible	Post. mandible
PHP	42	3	9	0	30
ModeratePCP	86	6	27	0	53
SeverePCP	99	15	36	12*	36*

*Statistically significant difference between PHP and severe PCP group and between moderate PCP and severe PCP group ($p < 0.05$).

	Implant diameter (mm)			Implant length (mm)			Implant design	
	3.3	4.1	4.8	8	10	12	Tissue level	Bone level
PHP	0	14	28	4	32	6	42	0
Moderate PCP	0	33	53	7	70	9	80	6
Severe PCP	12*	31	56	11	64	24	78	21*

*Statistically significant difference between PHP and severe PCP group and between moderate PCP and severe PCP group ($p < 0.05$).

TABLE 3 Size distribution of implants

TABLE 4 Periodontal parameters at the initial examination (T1) and at the follow-up (T2) of PHP, moderate PCP, and severe PCP groups

	Mean PPD (mm)	Mean BI	FMBS (%)	(PD ≥ 6 mm)%	(PD ≥ 5 mm)%
T1					
PHP	not recorded	not recorded	not recorded	–	–
Moderate PCP	2.98 ± 0.41	2.25 (1.95–2.62)	79.33 ± 22.59	2.38 (0.16–6.49)	10.47 (4.00–13.99)
Severe PCP	4.36 ± 0.76*	3.08 (2.83–3.53)*	97.05 ± 8.17*	20.63 (14.62–27.07)*	44.74 (33.94–54.76)*
T2					
PHP	2.16 ± 0.40	0.98 (0.43–1.29)	32.72 ± 23.40	–	–
Moderate PCP	2.40 ± 0.41†	0.82 (0.57–1.69)†	38.43 ± 26.72†	0.58 (0.00–1.69)†	1.92 (0.60–5.38)†
Severe PCP	2.85 ± 0.60†	1.36 (0.99–1.90)†	52.98 ± 27.55†	3.21 (1.19– 6.06)†	8.33 (3.87–15.59)†

Notes. Mean PPD and FMBS were expressed as mean ± SD.

Mean BI, (PPD ≥ 6 mm)% and (PPD ≥ 5 mm)% were expressed as median (Q1–Q3).

*Statistically significant difference between moderate PCP and severe PCP group ($p < 0.05$). †Statistically significant difference between T1 and T2 ($p < 0.05$).

4 | DISCUSSION

Numerous studies have demonstrated that a history of periodontitis was a risk of peri-implantitis (Heitz-Mayfield, 2008; Karoussis, Kotsovilis, & Fourmousis, 2007; Pesce et al., 2014; Renvert & Persson, 2009; Renvert & Quirynen, 2015). Most cohort studies classified patients into treated periodontitis and non-periodontitis group and the treated periodontitis group showed a greater risk of implant loss and peri-implantitis than the non-periodontitis group (De Boever, Quirynen, Coucke, Theuniers, & Boever, 2009; Evian et al., 2004; Karoussis et al., 2003; Roos-Jansaker, Renvert, Lindahl, & Renvert, 2006a, 2006b). Along with an increase in the number of related research, several recent studies focused particularly on the influence of various degrees of periodontal disease on the outcome of implant therapy. The results of these studies showed a statistically significant higher risk of peri-implant disease and implant failure in the group with severe periodontitis compared with the periodontally healthy group (Gatti, Gatti, Chiapasco, & Esposito, 2008; Levin, Ofec, Grossmann, & Anner, 2011; Rocuzzo et al., 2010, 2012, 2014). The present research differentiated degrees of periodontal disease based on the number and the depth of periodontal pockets. In accordance with results of above literatures, the outcomes of the present longitudinal cohort study showed that implants placed in the severe PCP group displayed a significantly higher prevalence of PDi ≥ 5 mm with BOPi+ than the PHP group. Therefore, the initial diagnosis of “severe periodontitis” was identified as a significant risk factor for peri-implant disease.

It is noteworthy that the characteristics of the participants selected from the Department of Periodontology at Peking University Hospital of Stomatology in this study were different from those in other relevant western researches. Cho-Yan, Mattheos, Nixon, and Ivanovski (2012) published a retrospective study comparing the clinical outcomes of implant treatment in PCP and PHP, and the PCP group in this study had a mean of 49.8 sites with PPD ≥ 4 mm, including a mean of 15.3 sites which had PPD ≥ 6 mm. A similar study of Rocuzzo et al. (2014) divided the patients into three groups

according to their periodontal condition, and the severe PCP had a mean of 31.9 sites with PPD ≥ 4 mm and a mean FMBS of 48.9%. However, the initial periodontal conditions of the patients in the present study were much worse. About 44.74% sites in severe PCP group patients showed PPD ≥ 5 mm and 20.63% sites showed PPD ≥ 6 mm at the initial examination. As in Chinese population, periodontitis was a common disease and quite a few patients had severe periodontal condition and long course of periodontal disease. A multicenter study in China reported by Han et al. (2016) also showed that the initial periodontal condition of the Chinese participants was much worse and the mean indices for plaque and bleeding on probing were shown to have a higher tendency during the 1-year evaluation when compared with other western centers which used the same inclusion criteria. In addition, due to the poor compliance in Chinese patients, supportive maintenance care was frequently neglected, denied, or omitted. About 67% of the implants in PHP, 50% in moderate PCP, and 49% in severe PCP couldn't receive a regular professional maintenance care every year in this study. It is important to note a higher maintenance frequencies in severe PCP patients when compared with the PHP and moderate PCP groups, which was similar to several previous studies (Levin et al., 2011; Rocuzzo et al., 2010, 2012, 2014), as these patients with severe periodontitis get a better motivation and compliance to maintenance care. It can be seen that the patients enrolled in this study were truly representative of developing country populations with a severe periodontal condition and poor compliance, which may be hazardous to peri-implant health.

In several previous studies, supportive periodontal therapy and regular maintenance of dental implant have been demonstrated to be essential to achieve high long-term survival and success rates of dental implants and their restorations. However, there was few research investigating the impact of maintenance intervals in patients with different periodontal condition on the incidence of biologic complication. The previous longitudinal studies classified patients into different groups according to different maintenance strategies rather than maintenance frequencies. Aguirre-Zorzano, Vallejo-Aisa, and Estefania-Fresco (2013) grouped the patients according to whether or not they

TABLE 5 Comparison of peri-implant parameters at the follow-up (T2) among PHP, moderate PCP and severe PCP groups

	Median (Q1–Q3)	Non-adjusted		Adjusted	
		β 95% CI	<i>p</i> -Value	β 95% CI	<i>p</i> -Value
Mean PLIi					
PHP	0.25 (0.00–0.50)	Reference		Reference	
Moderate PCP	0.50 (0.00–1.00)	0.16 (–0.04, 0.36)	0.1216	0.17 (–0.03, 0.37)	0.0896
Severe PCP	0.50 (0.00–1.00)	0.32 (0.09, 0.55)	0.006	0.32 (0.12, 0.51)	0.0017
Mean PDi (mm)					
PHP	2.33 (2.00–2.83)	Reference		Reference	
Moderate PCP	2.50 (2.17–2.83)	0.09 (–0.18, 0.36)	0.4928	0.13 (–0.12, 0.38)	0.3162
Severe PCP	2.67 (2.33–3.17)	0.41 (0.18, 0.65)	0.0006	0.57 (0.33, 0.81)	<0.0001
Mean Bli					
PHP	0.25 (0.00–2.00)	Reference		Reference	
Moderate PCP	0.50 (0.00–2.00)	0.09 (–0.30, 0.48)	0.6526	0.27 (–0.15, 0.70)	0.2071
Severe PCP	1.00 (0.50–2.00)	0.48 (0.12, 0.83)	0.008	0.71 (0.30, 1.13)	0.0007
Deepest PDi (mm)					
PHP	3.00 (3.00–3.50)	Reference		Reference	
Moderate PCP	3.00 (3.00–4.00)	0.16 (–0.14, 0.46)	0.3061	0.15 (–0.15, 0.46)	0.3271
Severe PCP	4.00 (3.00–4.00)	0.59 (0.31, 0.87)	<0.0001	0.71 (0.40, 1.03)	<0.0001
Mean BLi (mm)					
PHP	0.05 (–0.08–0.38)	Reference		Reference	
Moderate PCP	0.10 (–0.04–0.34)	0.03 (–0.21, 0.26)	0.8355	0.13 (–0.14, 0.40)	0.3334
Severe PCP	0.23 (0.00–0.50)	0.13 (–0.11, 0.38)	0.2909	0.22 (–0.01, 0.46)	0.0657
	N (%)	Non-adjusted		Adjusted	
		OR 95% CI	<i>p</i> -Value	OR 95% CI	<i>p</i> -Value
PDi \geq 5 mm and BOPI+					
PHP	3 (7.1%)	Reference		Reference	
Moderate PCP	8 (9.3%)	1.33 (0.32, 5.47)	0.6897	1.94 (0.41, 9.24)	0.4052
Severe PCP	21 (21.2%)	3.50 (0.90, 13.59)	0.0703	10.89 (2.34, 50.74)	0.0024

Notes. Comparisons of mean PLIi, mean PDi, mean Bli, mean deepest PDi, mean BLi were analyzed by generalized estimate equation (GEE) and linear regression model.

Comparison of prevalence of PDi \geq 5 mm and BOPI+ was analyzed by generalized estimate equation (GEE) and logistic regression model.

Adjusted for age, gender, smoking, follow up period, diameter of implant, length of implant, design of implant, and location of implant.

attended supportive periodontal therapy (SPT). Pjetursson et al. (2012) grouped the patients according to attending the SPT in University or in a private practice. Rocuzzo et al. (2012), Rocuzzo et al. (2014) grouped the patients according to whether or not they strictly adhere to SPT.

In the present study, the patients with different periodontal condition were further subdivided into two groups based on the frequency of maintenance therapy (a mean maintenance therapy interval of more than one year or not). The results showed that the prevalence of implant with PDi \geq 5 mm and BOPI+, deepest PDi, mean PDi, Bli, and PLIi were significantly higher in the "MF < 1 per year" group than the "MF \geq 1 per year" group for the severe PCP group, while the deepest PDi, mean PDi and PLIi were slightly but insignificantly higher in the "MF < 1 per year" group than the "MF \geq 1 per year" group for the moderate PCP group and

the PHP group. These results confirmed that severe periodontally compromised patients without regular maintenance tended to have a higher risk of peri-implant diseases. This gives us a hint that enrollment in regular SPT should be implemented to achieve high long-term survival and success rates of dental implants. With regard to PHP and moderate PCP, there was a trend toward improved peri-implant condition with a mean maintenance therapy interval of <1 year, but the differences did not reach significance. Therefore, in clinic we should assess the patient's risk for peri-implant disease so as to determine appropriate maintenance interval and plan. When compared with PHP and moderate PCP, the severe PCP may need a shorter maintenance interval to ensure the stability of the periodontal and peri-implant condition. The clinical parameters should be re-assessed at every follow-up visit to monitor periodontal condition and detect relapse or deterioration of

TABLE 6 Comparison of MF \geq 1 per year and MF $<$ 1 per year for peri-implant parameters at the follow-up (T2) in severe PCP group

	Median (Q1–Q3)	Non-adjusted		Adjusted	
		β 95% CI	p-Value	β 95% CI	p-Value
Mean PLIi					
MF \geq 1 per year	0.50 (0.00–1.00)	Reference		Reference	
MF $<$ 1 per year	1.00 (0.50–1.50)	0.39 (0.06, 0.71)	0.0202	0.44 (0.15, 0.73)	0.0027
Mean PDi (mm)					
MF \geq 1 per year	2.67 (2.33–3.00)	Reference		Reference	
MF $<$ 1 per year	3.00 (2.54–3.96)	0.61 (0.34, 0.88)	$<$ 0.0001	0.58 (0.32, 0.85)	$<$ 0.0001
Mean BLi					
MF \geq 1 per year	1.00 (0.50–2.00)	Reference		Reference	
MF $<$ 1 per year	1.75 (0.63–2.50)	0.53 (0.14, 0.91)	0.0077	0.74 (0.33, 1.15)	0.0004
Deepest PDi (mm)					
MF \geq 1 per year	3.00 (3.00–4.00)	Reference		Reference	
MF $<$ 1 per year	4.00 (3.00–5.00)	0.80 (0.31, 1.29)	0.0015	0.71 (0.30, 1.13)	0.0008
Mean BLi (mm)					
MF \geq 1 per year	0.22 (0.00–0.41)	Reference		Reference	
MF $<$ 1 per year	0.34 (0.07–0.90)	0.04 (–0.44, 0.52)	0.8605	–0.03 (–0.48, 0.42)	0.9003
	N (%)	Non-adjusted		Adjusted	
		OR 95% CI	p-Value	OR 95% CI	p-Value
PDi \geq 5 mm and BOPi+					
MF \geq 1 per year	8 (11.6%)	Reference		Reference	
MF $<$ 1 per year	13 (43.3%)	5.83 (2.60, 13.1)	$<$ 0.0001	8.23 (2.44, 27.78)	0.0007

Notes. Comparisons of mean PLIi, mean PDi, mean BLi, mean deepest PDi, mean BLi were analyzed by generalized estimate equation (GEE) and linear regression model.

Comparison of prevalence of PDi \geq 5 mm and BOPi+ was analyzed by generalized estimate equation (GEE) and logistic regression model.

Adjusted for age, gender, smoking, follow up period, diameter of implant, length of implant, design of implant, and location of implant.

periodontal infections. In accordance with the clinical parameters at follow-up, the maintenance interval can be shortened or prolonged. However, results of the present study which showed wide confidence intervals still have to be treated with some caution because of the limitations of the short follow-up period and the small sample size. Further study with longer follow-up period and larger sample size is needed to confirm our results.

In conclusion, the present study has indicated that (a) the patients with a history of severe periodontitis are recognized to be at greater risk of peri-implant disease (PDi \geq 5 mm with BOPi+) compared with the periodontally healthy patients. (b) Regular maintenance therapy can be considered the critical determinant of long-term outcome of dental implants. Irregular maintenance shows a negative impact on the prognosis of implant therapy especially in the severe PCP.

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CONFLICT OF INTEREST

No conflict of interest exists in this study, and the manuscript is approved by all authors for publication.

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REFERENCES

- Aguirre-Zorzano, L. A., Vallejo-Aisa, F. J., & Estefania-Fresco, R. (2013). Supportive periodontal therapy and periodontal biotype as prognostic factors in implants placed in patients with a history of periodontitis. *Med Oral Patol Oral Cir Bucal*, 18, e786–e792.
- Cho-Yan, L. J., Mattheos, N., Nixon, K. C., & Ivanovski, S. (2012). Residual periodontal pockets are a risk indicator for peri-implantitis in patients treated for periodontitis. *Clinical Oral Implants Research*, 23, 325–333. <https://doi.org/10.1111/j.1600-0501.2011.02264.x>
- De Boever, A. L., Quirynen, M., Coucke, W., Theuniers, G., & De Boever, J. A. (2009). Clinical and radiographic study of implant treatment outcome in periodontally susceptible and non-susceptible patients: A prospective longterm study. *Clinical Oral Implants*

- Research, 20, 1341–1350. <https://doi.org/10.1111/j.1600-0501.2009.01750.x>
- Evian, C. I., Emling, R., Rosenberg, E. S., Waasdorp, J. A., Halpern, W., Shah, S., & Garcia, M. (2004). Retrospective analysis of implant survival and the influence of periodontal disease and immediate placement on long-term results. *International Journal of Oral and Maxillofacial Implants*, 19, 393–398.
- Gatti, C., Gatti, F., Chiapasco, M., & Esposito, M. (2008). Outcome of dental implants in partially edentulous patients with and without a history of periodontitis: A 5-year interim analysis of a cohort study. *European Journal of Oral Implantology*, 1, 45–51.
- Han, J., Zhang, X., Tang, Z., Zhang, L., Shi, D., & Meng, H. (2016). A prospective, multicenter study assessing the DENTSPLY Implants, OsseoSpeed™ TX, length 6 mm in the posterior maxilla and mandible: A 1-year follow-up study. *Clinical Oral Implants Research*, 27, 452–457.
- Heitz-Mayfield, L. J. (2008). Peri-implant diseases: Diagnosis and risk indicators. *Journal of Clinical Periodontology*, 35, 292–304. <https://doi.org/10.1111/j.1600-051X.2008.01275.x>
- Heitz-Mayfield, L. J., & Huynh-Ba, G. (2009). History of treated periodontitis and smoking as risks for implant therapy. *International Journal of Oral and Maxillofacial Implants*, 24, 39–68.
- Hultin, M., Komiyama, A., & Klinge, B. (2007). Supportive therapy and the longevity of dental implants: A systematic review of the literature. *Clinical Oral Implants Research*, 18(Suppl 3), 50–62. <https://doi.org/10.1111/j.1600-0501.2007.01447.x>
- Karoussis, I. K., Kotsovilis, S., & Fourmoussis, I. (2007). A comprehensive and critical review of dental implant prognosis in periodontally compromised partially edentulous patients. *Clinical Oral Implants Research*, 18, 669–679. <https://doi.org/10.1111/j.1600-0501.2007.01406.x>
- Karoussis, I. K., Salvi, G. E., Heitz-Mayfield, L. J., Bragger, U., Hammerle, C. H., & Lang, N. P. (2003). Long-term implant prognosis in patients with and without a history of chronic periodontitis: A 10-year prospective cohort study of the iti dental implant system. *Clinical Oral Implants Research*, 14, 329–339.
- Levin, L., Ofec, R., Grossmann, Y., & Anner, R. (2011). Periodontal disease as a risk for dental implant failure over time: A long-term Historical cohort study. *Journal of Clinical Periodontology*, 38, 732–737. <https://doi.org/10.1111/j.1600-051X.2011.01745.x>
- Mazza, J. E., Newman, M. G., & Sims, T. N. (1981). Clinical and antimicrobial effect of stannous fluoride on periodontitis. *Journal of Clinical Periodontology*, 8, 203–212. <https://doi.org/10.1111/j.1600-051X.1981.tb02031.x>
- Mombelli, A., van Oosten, M. A. C., Schurch, E., & Lang, N. P. (1987). The microbiota associated with successful or failing osseointegrated titanium implants. *Oral Microbiology and Immunology*, 2, 145–151. <https://doi.org/10.1111/j.1399-302X.1987.tb00298.x>
- Monje, A., Aranda, L., Diaz, K. T., Alarcon, M. A., Bagramian, R. A., Wang, H. L., & Catena, A. (2016). Impact of maintenance therapy for the prevention of peri-implant diseases: A systematic review and meta-analysis. *Journal of Dental Research*, 95, 372–379. <https://doi.org/10.1177/0022034515622432>
- Pesce, P., Menini, M., Tealdo, T., Bevilacqua, M., Pera, F., & Pera, P. (2014). Peri-implantitis: A systematic review of recently published papers. *International Journal of Prosthodontics*, 27, 15–25. <https://doi.org/10.11607/ijp.3785>
- Pjetursson, B. E., Helbling, C., Weber, H. P., Matuliene, G., Salvi, G. E., Bragger, U., ... Lang, N. P. (2012). Peri-implantitis susceptibility as it relates to periodontal therapy and supportive care. *Clinical Oral Implants Research*, 23, 888–894. <https://doi.org/10.1111/j.1600-0501.2012.02474.x>
- Qi, X. (2008). *The Third National Oral Health Epidemiological Survey*. Beijing: People's Medical Publishing House.
- Renvert, S., & Persson, G. R. (2009). Periodontitis as a potential risk factor for peri-implantitis. *Journal of Clinical Periodontology*, 36(Suppl 10), 9–14. <https://doi.org/10.1111/j.1600-051X.2009.01416.x>
- Renvert, S., & Quirynen, M. (2015). Risk indicators for peri-implantitis. A narrative review. *Clinical Oral Implants Research*, 26(Suppl 11), 15–44. <https://doi.org/10.1111/clr.12636>
- Roccuzzo, M., Aglietta, M., Bunino, M., & Bonino, L. (2010). Ten-year results of a three arms prospective cohort study on implants in periodontally compromised patients. Part I: Implant loss and radiographic bone loss. *Clinical Oral Implants Research*, 21, 490–496.
- Roccuzzo, M., Bonino, L., Aglietta, M., & Dalmasso, P. (2012). Ten-year results of a three arms prospective cohort study on implants in periodontally compromised patients. Part II: Clinical results. *Clinical Oral Implants Research*, 23, 389–395.
- Roccuzzo, M., Bonino, L., Dalmasso, P., & Aglietta, M. (2014). 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. *Clinical Oral Implants Research*, 25, 1105–1112. <https://doi.org/10.1111/clr.12227>
- Roos-Jansaker, A. M., Renvert, H., Lindahl, C., & Renvert, S. (2006a). Nine- to fourteen-year follow-up of implant treatment. Part I: Implant loss and associations to various factors. *Journal of Clinical Periodontology*, 33, 283–289.
- Roos-Jansaker, A. M., Renvert, H., Lindahl, C., & Renvert, S. (2006b). Nine- to fourteen-year follow-up of implant treatment. Part III: Factors associated with peri-implant lesions. *Journal of Clinical Periodontology*, 33, 296–301.
- Simonis, P., Dufour, T., & Tenenbaum, H. (2010). Long-term implant survival and success: A 10–16 year follow-up of non-submerged dental implants. *Clinical Oral Implants Research*, 21, 772–777. <https://doi.org/10.1111/j.1600-0501.2010.01912.x>
- Sousa, V., Mardas, N., Farias, B., Petrie, A., Needleman, I., Spratt, D., & Donos, N. (2016). A systematic review of implant outcomes in treated periodontitis patients. *Clinical Oral Implants Research*, 27, 787–844. <https://doi.org/10.1111/clr.12684>

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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