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ORIGINAL ARTICLE

Incidence and prevalence of peri-implantitis and peri-implant mucositis 17 to 23 (18.9) years postimplant placement

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Abstract

Purpose: To evaluate the prevalence of peri-implantitis (PI) and peri-implant mucositis (PM) in a long-term follow-up with comparison among different PI and PM definitions, and to report on the incidence of PI.

Materials and Methods: In a retrospective clinical study five different PI and PM definitions were applied onto a population with 274 implants 17 to 23 years postimplant placement. Recommendations by the Eighth European Workshop on Periodontology (EWOP) were used as base reference. Clinical and radiological measurements were considered. Risk factors were evaluated in a regression analysis.

Results: After an average observation period of 18.9 years, 40.1% of the implants were diagnosed with PM and 15.0% with PI (Eighth EWOP). PI incidence reached 7.9% on implant level and 13.2% on patient level. Implants diagnosed with PI and progressive bone loss displayed exceptionally vertical bone defect configuration (BDC). Diabetes mellitus, smoking, regular maintenance, or a former periodontal infection did not show significant influence on the prevalence of peri-implant diseases. Patients with bruxism displayed significantly less PM and PI.

Conclusions: Vertical BDC seems to correspond with active PI, wherefore we estimate such a defining factor of importance. Diagnosis of PM and evaluation of probing pocket depths might be only of descriptive interest as they could lead to false-positive results.

KEYWORDS

bone loss, bone regeneration, clinical research, clinical study, defect configuration, mucositis, peri-implant lesions, peri-implantitis, retrospective

Mischa Krebs and Nikolina Kesar contributed equally to this study.

1 | INTRODUCTION

Mombelli et al introduced the term peri-implantitis (PI) to the clinical field of oral implantology and periodontology.[1] In the following, several studies have been published refining its definition. Comparable to periodontal diseases, that is, gingivitis and periodontitis, peri-implant mucositis (PM), and PI are distinguished. Whereas PM is described as a reversible inflammation of the peri-implant mucosa being diagnosed by bleeding on probing, PI is characterized by an irreversible peri-implant bone loss (BL) in addition to bleeding on probing.[2-4] Overall, PM and PI are infectious diseases.[3] Especially diabetes mellitus, smoking, a history of periodontitis as well as a combination of smoking and a prior periodontal infection were described as factors enhancing the risk of PI and PM.[5,6]

Since there are several suggestions on the level of BL defining PI as such, differing amounts in the prevalence of peri-implant diseases have been documented. Calculations range from 19% to 65% for PM and from 1% to 47% for PI.[7] To minimize scientific bias, Sanz and Chapple recommended for incidence studies the threshold level of BL to be chosen at 1.0 to 1.5 mm.[8] For prevalence studies a threshold level of BL of 2.0 mm is proposed, as baseline radiographs might be absent while the postimplant bone remodeling still needs to be included.[8]

Another aspect is a minimum time of 5 years after implant placement to judge on peri-implant diseases. Changes of bone level during that period might be exclusively based on physiological bone remodeling.[9] Although various studies claim long-term follow-up of more than 5 years, the inconsistency becomes evident when focused on the mean follow-up, which might be limited.[10]

The aim of our study was to explore and compare the prevalence of PM and PI based on different definitions when applied onto a patient cohort 17 to 23 years postimplant placement, and the influence of diabetes mellitus, smoking, regular maintenance as well as former periodontal or peri-implant infection. For descriptive reasons we also considered the incidence of PI.

2 | MATERIALS AND METHODS

2.1 | Study population

In a retrospective clinical study, data were collected from a patient pool listed in the program impDat (Kea Software GmbH, Pöcking, Germany) from a department of oral surgery of a university hospital. Patients receiving dental implants between 1991 and 1997 were included as meeting the following criteria:

- All inserted implants belong to one identical brand (Ankylos Classic; Dentsply Sirona Implants, Mölndal, Sweden).
- Definitive prosthetic rehabilitation within 18 months after implant placement.
- Presence of a radiograph directly after surgery (XR1).
- Presence of a radiograph directly after seating of the prosthetics (XR2).

Neither patients with horizontal nor with vertical bone grafting procedures were excluded from recruitment.

The study was reviewed and approved by the local university ethics committee based on the Declaration of Helsinki (in its actual, revised form). The eligible subjects were contacted by phone or mail and written informed consent was obtained from all participants.

2.2 | Clinical examination

Three examiners were calibrated for the assessment of probing pocket depths (PPD) and bleeding on probing (BOP). PPD were ascertained at six sites (distobuccal, midbuccal, mesiobuccal, mesiooral, midoral, and distooral) around each implant with a pressure-calibrated probe (Kerr Click-Probe, Orange, California), and BOP was documented as present or absent for each probing pocket. All measurements were made at least 5 minutes apart and were blinded to the other examining clinicians. Seventeen implants with a total of 102 measured sites, which were rated within the first month of the trial, were included into analysis. The intraclass correlation coefficient (ICC) was calculated to verify the intra- and interobserver reliability regarding PPD as continuous variable. To guarantee precise results, an unadjusted, two-way mixed test model with 95% confidence intervals (CIs) was chosen. Regarding the categorical variable BOP, Fleiss' kappa coefficient (κ) with 95% CI was assessed to confirm intra- and interobserver reliability. An ICC of 0.832 (CI 0.785-0.873) and κ = 0.822 (CI 0.772-0.872) could be obtained, indicating an "excellent"[11] and "almost perfect"[12] result, respectively.

2.3 | Radiological examination

A digital panoramic radiograph (XR3) was taken at recall examination (Orthophos XG3; Sirona Dental Systems GmbH, Bensheim, Germany). The analogue radiographs XR1 and XR2 were scanned and digitized (Microtek ScanMaker i800 Plus, Hsinchu, Taiwan; LaserSoft Imaging AG, Kiel, Germany) and stored in the Sidexis XG Database (Sirona Dental Systems GmbH). Prior to the final measurements of BL, two examiners were calibrated for evaluation of the radiographs. During the calibration process all measurements were performed by both examiners, who were blinded to each other's results. To assess intra- and interobserver reliability and the ICC for BL as continuous variable, the above-mentioned group of 17 implants was included into analysis, as previously described. An ICC of 0.935 (CI 0.894-0.964) was achieved, expressing "excellent"[11] reliability. The radiological examination process itself is depicted in the following. The known implant length (calibrated with the distance implant apex to implant shoulder) was used as reference. Peri-implant bone levels were measured at the mesial and distal implant shoulder (distance implant shoulder to bone level). Bone gain or subcrestally placed implants were indicated by negative (–) values, BL was indicated by positive (+) values according to the protocol of Gomez-Roman et al.[13,14] BL was calculated as difference XR2-XR1 (BL1) and XR3-XR2 (BL2). As all measurements were repeated at a separate occasion, the mesial and distal mean values were used for further calculations.

2.4 | Peri-implant disease definitions

The following peri-implantitis definitions (PID) were compared:

- PID1: BL ≥1.5 mm and BOP (based on Sanz and Chapple[8]).
- PID2: BL ≥2.0 mm and BOP (based on Sanz and Chapple[8]).
- PID3: BL ≥1.5 mm and BOP (based on Sanz and Chapple[8]), including vertical bone defect configuration (BDC; based on Zhang et al[15]).
- PID4: PPD ≥4.0 mm and BOP (based on Mombelli and Lang[16]).
- PID5: BL ≥1.5 mm, PPD ≥4.0 mm and BOP (based on Sanz and Chapple[8] and Mombelli and Lang[16]).

Considering the five different PID as depicted above, we reconstructed the following peri-implant mucositis definitions (PMD):

- PMD1: BL <1.5 mm and BOP (reconstructed on Sanz and Chapple[8]).
- PMD2: BL <2.0 mm and BOP (reconstructed on Sanz and Chapple[8]).
- PMD3: BL <1.5 mm and BOP (reconstructed on Sanz and Chapple[8]) *or* BL ≥1.5 mm and vertical BDC-absence and BOP (reconstructed on Sanz and Chapple[8] and Zhang et al[15]).
- PMD4: PPD <4.0 mm and BOP (reconstructed on Mombelli and Lang[16]).
- PMD5: BL <1.5 mm and BOP (reconstructed on Sanz and Chapple[8]) *or* BL ≥1.5 mm and PPD <4.0 mm and BOP (reconstructed on Sanz and Chapple[8] and Mombelli and Lang[16]).

In case of implants classified with PI according to PID1, radiographs from control visits 5 years prior to the last examination were digitized and evaluated for progressive BL (calculated as difference XR3-XR4) and defect configuration. The latter was judged upon a concept by Zhang et al.[15] Especially the type 2, wedge-shaped BDC, as entitled by the authors, was used as matching reference for vertical BDC in our study. It is classified as a bone defect characterized by a straight or convex wall.[15]

Additionally, all participants were interviewed. The questionnaire consisted of a history on diabetes mellitus, smoking, periodontitis, and supportive periodontitis therapy, earlier manifestation of PI and PI therapy as well as regular maintenance. Besides, the patient charts were screened for detailed information.

2.5 | Statistical analysis

All statistical evaluations, including the previously mentioned estimation of intra- and interobserver reliability, were conducted using SPSS (IBM SPSS Statistics, Version 22.0, Armonk, New York). One main outcome of the study was to evaluate the prevalence of PM and PI and to compare it upon different peri-implant disease definitions, as well as to evaluate the incidence of PI. Hence, the date of implant placement was defined as baseline. The date of recall examination was set as endpoint to estimate prevalence, and a time range of 17 years postimplant placement was defined to assess incidence. Differences between the several groups of peri-implant disease definitions were analyzed by the Pearson chi-squared test. Furthermore, associations between the measured parameters PPD and BOP, BL and BOP, BL and PPD were also represented by the Pearson chi-squared test. Another main outcome of the study was to evaluate the influence of risk factors on the prevalence of PM and PI. Due to the low number of exposed implants and to avoid overfitting, we decided to perform a binary regression analysis instead of a multinomial regression analysis. To create a dependent variable, implants from both the PM and PI cohort were grouped against a healthy reference cohort. Diabetes mellitus, smoking, bruxism, regular maintenance, a history of periodontitis, both a history of periodontitis and smoking, and a history of PI were included as independent variables all together in a single step. The effect size of each independent variable was expressed by the adjusted odds ratio (OR) and corresponding 95% CI. The Hosmer-Lemeshow test was applied to confirm the goodness-of-fit for the designed model. The level of significance was set at $P \leq .05$.

3 | RESULTS

The inclusion criteria were fulfilled by 375 patients. Of those, 106 participants (50 male and 56 female) with a total number of 274 implants could be enrolled (Figure 1 and Table 1). The average age of the patients was 70.9 years (range: 45-91 years, median: 71 years) and the average observation time was 18.9 years (range: 17.3-23.2 years, median: 18 years).

Probing pocket depths ≥4.0 mm were measured in 126 implants (46.0%) and BOP occurred in 151 implants (55.1%). The relationship between PPD and BOP was found to be significant ($P = .001$), as with PPD ≥4.0 mm most of the implants were diagnosed with BOP. The implants were on average inserted −0.39 mm ± 0.70 mm subcrestally (median: 0.00 mm, XR1). After seating of the prosthetics, the bone level was on average 0.23 mm ± 0.86 mm (median: 0.00 mm, XR2) and at recall appointment 0.77 mm ± 1.42 mm (median: 0.52 mm, XR3). This resulted in BL1 of −0.62 mm ± 0.87 mm (median: 0.00 mm) and BL2 of

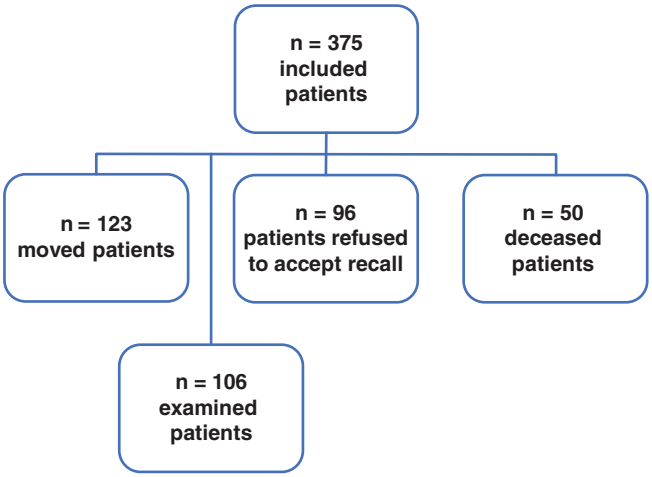

FIGURE 1 Distribution of the included subjects according to the eligibility criteria. Several patients refused to accept an appointment in the context of the study mostly due to severe health issues

−0.54 mm ± 1.20 mm (median: −0.07 mm). An association between BL and BOP could not be found (P = .909), while a significant association was calculated between BL and PPD (P = .022).

TABLE 1 Characteristics of indication class, surgical site, bone grafting and prosthetic rehabilitation on implant level

	n = 274	%
Indication classes[17]		
Ia: Single tooth in anterior region	8	2.9
Ib: Single tooth in posterior region	33	12.0
IIa: Free-end gap	90	32.8
IIb: Interdental space	42	15.3
IIc: Strongly reduced residual teeth	38	13.9
IIIa: Edentulous upper jaw	12	4.4
IIIb: Edentulous lower jaw	51	18.6
Placement		
Maxilla	117	42.7
Mandible	157	57.3
Bone grafting		
Autologous graft	7	2.6
Xenogeneic graft[a]	12	4.4
Mixed graft	3	1.1
None	252	92.0
Prosthetic restoration		
Single crown	72	26.3
Single bridge	122	44.5
Full-arch bridge	16	5.8
Prosthesis	64	23.4
Retention of primary and secondary crowns		
Cement-retained[b]	263	96.0
Screw-retained	11	4.0

[a]Geistlich Biomaterials, Wolhusen, Switzerland.
[b]TempBond®, Kerr™, Orange, California.

Based on the clinical and radiological measurements, the prevalence of PM and PI referring to each of the five definitions was determined, and differences between the groups were compared by the Pearson chi-squared test. According to the reference definitions PID1 and PMD1, a PI prevalence of 15.0% and PM prevalence of 40.1% was found on implant level (Table 2). Eleven (26.8%) of those implants diagnosed with PI (PID1) displayed progressive BL over a 5-year period prior to examination. All of them were accompanied by exclusively vertical BDC. When vertical BDC itself, besides BL ≥1.5 mm and BOP was considered as a defining factor of PI, a significantly

TABLE 3 Implants with previous peri-implantitis therapy and their outcome at recall according to peri-implantitis definition 1 (PID1) and peri-implant mucositis definition 1 (PMD1)

Implant	Region	Treatment	Status (PID1/PMD1)
1	21	Scaling	PM
2	22	Scaling	PM
3	31	Scaling	PM
4	41	Scaling	PM
5	47	Scaling	PM
6	32	Scaling	PI
7	14	Scaling	Healthy
8	34	Implantoplasty	PI
9	33	Implantoplasty	PM
10	12	Scaling	PM
11	46	Scaling	PM
12	Unknown	Unknown	PI[a]
13	36	GBR	Healthy
14	35	GBR	PM
15	16	Scaling	PM
16	15	Scaling	PI
17	35	Scaling	Healthy

Abbreviations: GBR, guided bone regeneration; PI, peri-implantitis; PM, peri-implant mucositis.
[a]All implants of that patient were diagnosed with PI at recall.

TABLE 2 Distribution of implants and prevalence of peri-implantitis and peri-implant mucositis according to the five definitions

	Peri-implantitis		Peri-implant mucositis		Healthy		Total		
Definition	n	%	n	%	n	%	n	%	*P*-value
1	41	15.0	110	40.1	123	44.9	274	100.0	
2	31	11.3	120	43.8	123	44.9	274	100.0	.402
3	19	6.9	132	48.2	123	44.9	274	100.0	**.007**
4	81	29.6	70	25.5	123	44.9	274	100.0	**≤.001**
5	29	10.6	122	44.5	123	44.9	274	100.0	.262

Note: Peri-implantitis definition 1 (PID1) and peri-implant mucositis definition 1 (PMD1) were used as base references concerning statistical differences between the groups upon Pearson chi-squared test.
Peri-implantitis definitions (PID): PID1: Bone loss (BL) ≥1.5 mm and bleeding on probing (BOP); PID2: BL ≥2.0 mm and BOP; PID3: BL ≥1.5 mm and BOP, including vertical bone defect configuration (BDC); PID4: PPD ≥4.0 mm and BOP; PID5: BL ≥1.5 mm, PPD ≥4.0 mm and BOP. Peri-implant mucositis definitions (PMD): PMD1: BL <1.5 mm and BOP; PMD2: BL <2.0 mm and BOP; PMD3: BL <1.5 mm and BOP *or* BL ≥1.5 mm and vertical BDC-absence and BOP; PMD4: PPD <4.0 mm and BOP; PMD5: BL <1.5 mm and BOP *or* BL ≥1.5 mm and PPD <4.0 mm and BOP. The bold values of significance was $\alpha = 0.05$.

TABLE 4 Impact of risk factors on the prevalence of a peri-implant disease (PID1 and PMD1) as estimated by binary logistic regression analysis

	Implants at risk n = 274	Peri-implant disease		
		OR	95% CI	*P*-value
Diabetes mellitus (no vs yes)	256/18	1167	0.423 to 3.219	.766
Smoking (no vs yes)	245/29	2486	0.557 to 11.093	.233
Bruxism (no vs yes)	227/47	0.476	0.236 to 0.959	**.038**
Regular maintenance (yes vs no)	209/65	1608	0.878 to 2.944	.124
History of periodontitis (no vs yes)	150/124	0.864	0.513 to 1.456	.583
HOP and smoking (no vs yes)	255/19	0.515	0.085 to 3.127	.471
History of peri-implantitis (no vs yes)	257/17	4566	1.248 to 16.704	**.022**

Abbreviations: CI, confidence interval; HOP, history of periodontitis; OR, odds ratio.

TABLE 5 Descriptive distribution of the diagnosed implants (PID1 and PMD1) and assessed risk factors

	Healthy n = 123 (%)	PM n = 110 (%)	PI n = 41 (%)
Diabetes mellitus			
No	115 (93.5)	104 (94.5)	37 (90.2)
Yes	8 (6.5)	6 (5.5)	4 (9.8)
Smoking			
No	112 (91.1)	95 (86.4)	38 (92.7)
Yes	11 (8.9)	15 (13.6)	3 (7.3)
Bruxism			
No	97 (78.9)	91 (82.7)	39 (95.1)
Yes	26 (21.1)	19 (17.3)	2 (4.9)
Regular maintenance			
Yes	100 (81.3)	75 (68.2)	34 (82.9)
No	23 (18.7)	35 (31.8)	7 (17.1)
History of periodontitis			
No	65 (52.8)	64 (56.2)	21 (51.2)
Yes	58 (47.2)	46 (41.8)	20 (48.8)
HOP and smoking			
No	115 (93.5)	101 (91.8)	39 (95.1)
Yes	8 (6.5)	9 (8.2)	2 (4.9)
History of peri-implantitis			
No	120 (97.6)	100 (90.9)	37 (90.2)
Yes	3 (2.4)	10 (9.1)	4 (9.8)

Abbreviations: HOP, history of periodontitis; PI, peri-implantitis; PM, peri-implant mucositis.

smaller number of implants was diagnosed with PI (PID3, $P = .007$) in comparison to the reference definition. The prevalence of PI significantly increased instead, when PPD ≥4 mm and BOP were the only defining criteria without inclusion of any BL threshold (PID4, $P \leq .001$). On the contrast, bone grafted sites vs non-bone grafted sites did not differ significantly ($P = .438$) in the prevalence of peri-implant diseases (PID1 and PMD1), as assessed by the Pearson chi-squared test.

Fourteen out of 106 patients with a total of 22 implants underwent at least once PI therapy. A positive outcome could be achieved in 17 implants (6.2%), of whom 12 were treated by scaling. Two implants were treated by implantoplasty and another two implants by guided bone regeneration with autologous and/or xenogeneic grafts. For one implant, the chosen therapy remained unknown. Based on PID1 and PMD1, at recall 4 of the mentioned 17 implants were diagnosed with PI, 10 implants with PM, 3 implants were without any peri-implant disease (Table 3). Still, 5 of 22 implants failed successful PI treatment and needed to be explanted in consequence. As their PI therapy had been performed alio loco, information on the treatment modality stayed uncertain. Overall, the incidence of PI reached 7.9% on implant level and 13.2% on patient level in a time range of 17 years postimplant placement.

None of the proposed risk factors diabetes mellitus, smoking, absence of regular maintenance, history of periodontitis, nor a combination of smoking and history of periodontitis showed significant influence on the development of a peri-implant disease (PID1 and PMD1), as identified by binary regression analysis. Patients with bruxism displayed a significantly lower prevalence (OR 0.469; CI 0.234-0.937; $P = .032$), whereas subjects with a previous manifestation of PI were prone to a recurrent peri-implant disease (OR 4.566; CI 1.248-16.704; $P = .022$; Table 4). The goodness-of-fit for the presented statistical model could be confirmed by the Hosmer-Lemeshow test with $P = .898$ and thus a high agreement between the observed and expected number of cases. A descriptive overview on the distribution of the diagnosed implants and the assessed risk factors is given in Table 5.

4 | DISCUSSION

Long-term studies on biological and technical complications of implants and the incidence and prevalence of peri-implant diseases are rare.[18] Predominantly observation periods of 5 to 10 years have been documented in meta-analyses.[19-23] The difficulty, as shown in our study, is based on limitations obtaining a study cohort several years after implant placement. Moreover, there is no consensus upon a uniform definition of peri-implant diseases, especially with regards to PI. Therefore, we considered at the time of study design current recommendations by Sanz and Chapple[8] as standard definition. To the extent of our knowledge, this is one of the first studies addressing

the prevalence of peri-implant diseases based on the entitled recommendations after an average period of 18.9 years postimplantation and with a total number of 274 implants.

According to the recommendations mentioned above, a prevalence of PI of 15.0% on implant level (PID1) could be calculated in our study. Adell et al in early years already documented a mean value of 1.5 mm of BL after wound healing and during the first year after seating of the prosthetics.[22] This fact implicates, that any other BL might be based on unphysiological reasons. On the other hand, numerous publications describe a larger amount of BL than 1.5 mm to be required for this purpose.[7,20,22] Those studies neglect that radiologically measured values are often smaller than in direct clinical comparison,[24-26] and that BL usually first becomes detectable when exceeding on average 0.47 mm,[27] why a threshold level of 0.5 mm as measurement error should be respected.[4] Digital radiography with the capabilities of both digital measurement and image editing, as applied in our study, is able to improve the quality of the results.[14] Overall, every BL needs to be counted suspicious ahead of PI. Since only implants with present baseline radiographs were examined, we decided to use the threshold level of 1.5 mm instead of 2.0 mm, as suggested for prevalence studies.

Compared to PID1, the proportion of PI as diagnosed according to PID2 was not significant. This is obvious, since the wider the thresholds are set (2.0 mm compared to 1.5 mm), the smaller the number of affected implants. Still, it justifies the limit proposed by Sanz and Chapple to be at 2.0 mm, if baseline radiographs are missing.[8] There are no significant discrepancies to be expected diagnosing implants with PI.

Some authors pointed out that there is neither an association between BDC nor a linearity of BL regarding PI.[28,29] Our evaluated implants diagnosed with PI (PID1) and progressive BL displayed exceptional vertical BDC. This progression corresponds with the picture of active PI. Exactly the latter observation is relevant in everyday clinical practice, as it is crucial to diagnose such cases of active PI and initiate treatment. Considering vertical BDC besides BL ≥1.5 mm and BOP (PID3), the prevalence of PI significantly decreased to 6.9% in our study.

The CIST (Cumulative Interceptive Supportive Therapy) by Mombelli and Lang aims to provide a scheme for early detection and adequate treatment of peri-implant diseases.[16] Among other parameters, pocket probing is recommended, whereby measurements ≥4.0 mm are set as threshold value indicating PI,[16] as on the contrary, in disease-free implants PPD ≤3.0 mm were described as physiological.[30-33] Therefore, we included PPD ≥4.0 mm in our definitions (PID4 and PID5). That theory is still up to date, as recent observations reported higher PPD of 4.0 to 6.0 mm predominantly in affected implants.[34] Regarding PID4 (PPD ≥4.0 mm and BOP) a significantly increased amount of PI was diagnosed, when compared to the recommended definition (PID1). Such a result needs to be classified under consideration of PID5 (BL ≥1.5 mm, PPD ≥4.0 mm and BOP): On the one hand, 29.6% of the implants showed PI (PID4), but finally only 10.6% were accompanied with additional BL (PID5). For this reason, high PPD should not be assumed as indicating or predictive value of BL. Moreover, several factors such as scaling of the probe, probing pressure, inflammation of the peri-implant tissue, implant design, free implant threads, and the prosthetic supra-construction are known to cause false PPD results.[16,35-38] Thus, we do not consider PPD as a defining factor in the classification of peri-implant diseases.

Even though diabetes mellitus, smoking and a history of periodontitis, and a combination of smoking and a history of periodontitis were described as risk factors for PI,[5,6] no significant impact on the development of PI and PM could be found in our cohort. Neither absence of regular maintenance showed impact on the prevalence of the forehand mentioned diseases. This might be clarified to a certain extent: All our diabetic patients were under close guidance by a diabetologist and regularly checked with emphasis on the HbA_{1c}-value. Moreover, the treatment protocol of our oral surgery department requires, that all individuals undergoing implant placement have successfully completed supportive periodontitis therapy, if necessary. Interestingly, patients with bruxism displayed a significantly lower prevalence of peri-implant diseases. Even though, as far as we know, similar results have been reported only by an animal study,[39] we assume that moderate high forces might lead to a denser bone formation around the implant neck due to remodeling, which could result in a higher resistance to bacterial invasion.

As it is clear, the definitions and therefore differing amounts of prevalence of PM depend on the corresponding definitions of PI. However, in four out of five PMD over 40% of the implants were diagnosed with PM, with most of them never being diagnosed with PI during an average observation period of 18.9 years. If PM had a realistic predictive value and if it persisted over a longer period, it is likely that a higher prevalence of PI could be expected. Thus, studies on the incidence or prevalence of PM should be of subordinate scientific interest, since they are of descriptive character and not comparable. BOP might be available just at a single point of time as during appointment. As it affects PID in general, it may be misleading and causal for false-positive results. This might explain, why we could prove significant impact of previous PI on the prevalence or, respectively, recurrence of peri-implant diseases. Nevertheless, the diagnosis of PM offers a helpful visualization to motivate affected patients improving oral hygiene.

Within the major limitations of our investigation, being of retrospective character and the difficulty, as mentioned before, obtaining a satisfactory number of subjects, our study contains the following strengths besides the long observation time: There are still controversial assumptions on the impact of implant surface on the development of peri-implant diseases.[40] To minimize bias, we only reexamined implants of one identical system. Those are characterized by a machined neck and a sand blasted titanium body.[18] Information varies, whether the type of luting cement promotes the development of PI shortly after insertion of the prosthetic restoration, resulting in persistent BL.[41,42] In our cohort, all cement-retained restorations were inserted with zinc oxide-eugenol cement.

Recently a consensus report introduced refined case definitions of PM and PI with respect to usage either in daily clinical practice or in epidemiological studies.[4] In short, a standard definition on the amount of BL to be identifiable for PI remains unclarified. Nevertheless, we believe, that those definitions are highly suitable in everyday practice: Any pathologic changes to previous examinations,[4] are besides academic interest first and foremost of relevance to diagnosis and treatment of the

individual patient and implant, so it is important to recognize them at all. Still, when referring to epidemiological studies we favor the concept by Sanz and Chapple,[8] with its defined and low threshold levels of BL.

5 | CONCLUSIONS

In comparison to other PID and with respect to the latest revisions,[4] the definition presented by Sanz and Chapple[8] seems satisfactory in everyday clinical usage and even more in clinical studies. Noteworthy are the threshold levels of BL at 1.5 mm, respectively, 2.0 mm. Moreover, we recommend a threshold level of 1.5 mm to be used as well for prevalence studies, if baseline radiographs are available. PPD should not be considered as a defining factor in PID, often not correlating with a PI diagnosis. The assessment is too technique-sensitive and error-prone to be used for such purposes. Our results from a limited group of infected implants suggest that BDC should be considered in PID. All implants with progressive BL were exclusively accompanied by vertical BDC, which might indicate active PI. The inclusion of BDC would also help minimizing false-positive results, wherefore we are in favor of further investigations focusing on the impact of BDC within larger study groups, as it is impossible to distinguish between BOP as acute or chronic event besides BL. Especially the latter needs to be considered, wherefore the diagnosis of PM is of primarily descriptive interest.

Bone grafting either with autologous or xenogeneic bone substitute materials did not display a significant association with the prevalence of PM and PI, nor did diabetes mellitus, smoking, regular maintenance, and former periodontal infection show further significant impact in our group.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

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