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The prevalence of peri-implant diseases around subcrestally placed implants: A cross-sectional study

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Abstract

Objectives: To evaluate the prevalence of peri-implant health, peri-implant mucositis or periimplantitis for subcrestally placed implants (1–3 mm) on the short-, medium- and long term.

Material and Methods: Two hundred patients were enrolled in this cross-sectional study that were treated and screened during regular maintenance visits at one university center. A total of 657 implants were evaluated. Peri-implant health and diseases were assessed according to predefined case definitions. Binary logistic regression was used to assess the correlation with local and systemic factors.

Results: After a median function time of 9.36 ± 6.44 years (range: 1–26 years), the prevalence of peri-implant mucositis and peri-implantitis was 66.5% and 15.0%, at the patient level, corresponding to 62.6% and 7.5%, at the implant level, respectively. Peri-implantitis was significantly associated with patients' history of periodontitis (odds ratio, OR 5.33).

Conclusion: Peri-implant diseases were a common finding around subcrestally placed implants.

KEYWORDS
epidemiology, peri-implant diseases, prevalence

1 | INTRODUCTION

Peri-implant diseases refer to a pathological condition affecting the peri-implant tissues at endosseous dental implants in function (Berglundh et al., 2018). They basically comprise two disease entities: peri-implant mucositis and peri-implantitis (Berglundh et al., 2018). Whereas peri-implant mucositis is defined as inflammation restricted to the soft tissues, peri-implantitis also features a progressive loss of the supporting bone (Berglundh et al., 2018). Even though substantial evidence supports the bacterial etiology of peri-implant diseases, several patient- and implant-related factors have been shown to increase the probability of their development (Berglundh et al., 2018; Heitz-Mayfield & Salvi, 2018). These include a history of periodontitis, poor dental plaque control skills, and irregular maintenance care after implant placement (Berglundh et al., 2018; Heitz-Mayfield & Salvi, 2018). Additionally, factors such as submucosal cement remnants, a lack of keratinized mucosa, and improper implant positioning are considered as local risk indicators for peri-implantitis (Berglundh et al., 2018).

Subcrestal implant placement is frequently chosen to obtain esthetically pleasing results, particularly in esthetically demanding areas (Degidi et al., 2011; Stein et al., 2009). Indeed, certain implant

designs with roughened implant shoulders have been introduced to the market to support deep implant insertion protocols, and especially to enhance bone stability in the area of the implant–abutment connection (Nentwig, 2004). A recent clinical analysis has increased the focus on the peri-implant mucosal tunnel (i.e., the distance between the implant–prosthesis interface and the soft tissue margin), indicating that deeper implant placement increases the mucosal tunnel's depth, which subsequently may compromise the implant site's cleansability and subsequently favor the peri-implant diseases (Chan et al., 2019). Additionally, as suggested by numerous pre-clinical and clinical data, subcrestal implant placement is associated with more extensive primary bone remodeling, which may further increase the depth of the transmucosal tunnel (Chan et al., 2019; Schwarz et al., 2014).

Currently, evidence on the impact of subcrestal implant placement on peri-implant tissue health is scarce. Therefore, this study was aimed at evaluating the prevalence of peri-implant diseases at subcrestally placed implants.

2 | MATERIALS AND METHODS

2.1 | Study design and participants

For this cross-sectional analysis, 202 partially or fully edentulous patients exhibiting two-piece platform-switched tapered connection implants (Ankylos®, Dentsply Sirona Implants) were screened during regular maintenance visits at the Department of Oral Surgery and Implantology, Goethe University, Carolinum. All implants were placed according to the manufacturer's surgical protocol (1–3 mm subcrestally) at the Department of Oral Surgery and Implantology, Goethe University, Carolinum, Frankfurt, Germany, by three oral surgeons with more than 3 years of experience. Each patient had received a detailed description of the procedure, and an informed consent form was obtained prior to participation.

The study protocol was in accordance with the Helsinki Declaration of 1975 (revised in August 2018) and approved by the Ethics Committee of the Goethe University. The present study reporting considered the STROBE (The Strengthening the Reporting of Observational Studies in Epidemiology) guidelines (von Elm et al., 2014).

2.2 | Inclusion and exclusion criteria

For patient selection, the following inclusion criteria were defined:

(1) patient age > 18 years; (2) partially/fully edentulous patients rehabilitated with at least one Ankylos® implant; (3) attendance of yearly routine implant maintenance appointment; (4) attendance of individualized periodontal/peri-implant supportive therapy at the Department of Oral Surgery and Implantology at Goethe University; and (5) non-smokers and smokers included.

For patient selection, the following exclusion criteria were defined (Schwarz et al., 2017a):

1. No uncontrolled systemic diseases which could influence the outcome of implant therapy (e.g., diabetes (HbA1c > 7), osteoporosis);
2. No intake of medications which may have an effect on bone turnover and mucosal healing (i.e., steroids, antiresorptive therapy) at last 10 years prior to the implant placement;
3. No pregnancy or breastfeeding women.

2.3 | Investigators meeting and calibration

Prior to the start of the study, a calibration meeting was held with each examiner (KO, AB, AR) to standardize (pseudonymous) data acquisition and the assessment of study variables. For the calibration of the examiners, double measurements were performed with a 5-min interval of the assessed clinical parameters in five patients with a total of 15 implants. The calibration was acceptable when repeated measurements were similar >95% level. The calculated mean inter-examiner variability between the repeated measurements for the assessed clinical parameters ranged from 96.0 ± 3.2% to 98 ± 0.9%. The documentation of demographic study variables, implant sites characteristics, and clinical measurements were documented using a standardized data extraction template.

2.4 | Demographic data and implant site characteristics

The following study variables were assessed:

(1) patient age, (2) gender, (3) history of (treated or current) periodontitis (extracted from the patient record based on the periodontal screening index (PSI) score value ≥ 3; 4) smoking habits (i.e., non-smoker or smoker), (5) implant functioning time after implant placement, (6) implant location (i.e. upper or lower jaw, anterior (i.e. canine to canine) or posterior (i.e., premolar and molar region) segments), (7) implant diameter, (8) bone augmentation procedures (none, one-stage, two-stage), (9) type of prosthesis (i.e., fixed or removable), and (10) soft tissue augmentation procedures (none, connective tissue graft (CTG), free gingival graft (FGG), CTG + FGG).

All patients diagnosed for periodontitis received appropriate treatment procedures at the Goethe University Clinic.

2.5 | Clinical measurements

The following clinical parameters were assessed at each implant site using a periodontal probe (PCP-UNC 15, Hu-Friedy, Chicago, USA):

(1) plaque index (PI) (Loe, 1967); (2) bleeding on probing (BOP) – measured as presence/absence; (3) probing depth (PD) – measured from the mucosal margin to the probable pocket; (4) mucosal recession (MR) – measured from the restoration margin to the mucosal margin; (5) keratinized mucosa (mm); (6) suppuration (SUPP) – measured as presence/absence.

Modified PI, BOP, PD, SUPP, and MR measurements were performed at six aspects per implant: mesiobuccal (mb), midbuccal (b), distobuccal (db), mesiooral (mo), midoral (o), and distooral (do). KM measurement were performed at three aspects per implant: mesiobuccal (mb), midbuccal (b), and distobuccal (db).

When the clinical signs suggested the presence of peri-implant tissue inflammation (i.e., the presence of BOP), non-standardized panoramic radiographs were taken and compared with a baseline radiograph obtained at the time of prosthesis installation. To account for radiographic measurement errors, a threshold of 1.0 mm (manually assessed from the implant neck to the crestal bone level at both interproximal aspects using a grid) was considered for the assessment of bone loss (Sanz et al., 2012).

2.6 | Case definition

Based on the consensus report of Workgroup 4 of the 2017 World Workshop on the classification of periodontal and peri-implant diseases and conditions, the following case definitions were applied (Berglundh et al., 2018):

1. Peri-implant tissue health defined as an absence of clinical signs of inflammation, such as BOP/SUPP on gentle probing, no increase in PDs compared to previous examinations, and an absence of bone loss beyond crestal bone level changes resulting from initial bone remodeling.
2. Peri-implant mucositis defined as the presence of BOP and/or SUPP on gentle probing with or without increased PDs compared to previous examinations and an absence of bone loss beyond crestal bone level changes resulting from initial bone remodeling.
3. Peri-implantitis defined as the presence of BOP and/or SUPP on gentle probing, increased PDs compared to previous examination, and the presence of radiographic bone loss at the final follow-up compared to the baseline (i.e., radiographs taken following the placement of the final prosthetic reconstruction).

All patients diagnosed for peri-implant diseases received appropriate treatment procedures at respective implants.

2.7 | Statistical analysis

An a priori sample size calculation considered a reported (i.e. expected) prevalence of peri-implantitis of 15.0% (Schwarz et al., 2018) and a type 1 error of 5%. A total of at least 156 patients were required to reach a 95% chance of detecting per-implantitis (OpenEpi).

A commercially available software program (SPSS Statistics version 26.0, IBM Corp.) was used for data analyses. Descriptive statistics was calculated for mPI, BOP, PD, KM and MR. The analyses were performed at both patient and implant levels. A binary logistic regression analysis defining the patient as statistical unit correlated the events "healthy", "peri-implant mucositis" and "peri-implantitis" with the following patient-related factors: mPI (<1/>1), smoking (yes/no), history of periodontitis (yes/no), and smoking + history of periodontitis (yes/no). Final models for the events healthy, peri-implant mucositis, and peri-implantitis were established by the backward elimination (Wald) of non-significant factors. Estimated odds ratio (OR) estimated and 95% confidence intervals (95% CI) were retrieved from the intercept of each factor).

3 | RESULTS

3.1 | Demographics and implant site characteristics

For this cross-sectional analysis, a total of 202 patients were screened. Two patients refused to take a part in the study; therefore, finally 200 partially or fully edentulous patients (118 female and 82 male) exhibiting 657 two-piece platform-switched tapered connection implants (Ankylos®, Dentsply Sirona Implants) were selected.

The demographic data and implant site characteristics of the study population are presented in Table 1.

In particular, the mean age of the included patients was 62.68 ± 14.31 years (median: 64.37 years; range: 18.96–94.42 years). The majority of the patients (56%) had a history of periodontitis, whereas smokers comprised a minority of the enrolled patient group (7%; Table 1).

Mean implant functioning time amounted to 9.36 ± 6.44 years (range: 1–26 years), with the vast majority of the implants (69%) being in function for longer than 60 months. The most frequent implant diameters and lengths were 3.5 mm (62%) and 11 mm (62%), respectively. Most of the implants were placed in the posterior segment of both the upper (70%) and lower jaws (76%), were associated with no bone augmentation procedures (54%) and restored with fixed prosthetic reconstructions (75%) (Table 1).

3.2 | Clinical measurements and prevalence of peri-implant diseases

At both patient and implant levels, median mPI and BOP scores were commonly low and amounted to 0.33 and 0.33 and 25% and 16.60%, respectively (Table 2). The estimated median PD and KM values at the patient level amounted to 2.81 mm and 2.85 mm, respectively. The corresponding values at the implant level analysis were 2.83 mm and 3.0 mm. The mean radiographic marginal bone loss was 0.7 ± 1.52 mm at the patient level and 0.44 ± 1.18 mm at the implant level. Furthermore, the mean registered MR was 0.14 mm at the patient level and amounted to 0.16 mm at the implant level, respectively. SUPP was detected in 4% of the implants.

According to the given case definitions, 18.5% of the enrolled patients presented peri-implant tissue health, whereas the majority of the patients (81.5%) were diagnosed with peri-implant diseases.

In particular, 66.5% of the patients were diagnosed with peri-implant mucositis, and the remaining 15% were diagnosed with peri-implantitis. Based on the implant-level analysis, the corresponding values were 29.9% (healthy peri-implant conditions), 62.6% (peri-implant mucositis), and 7.5% (peri-implantitis), respectively (Table 3; Figures 1 and 2).

TABLE 1 Demographic data and implant site characteristics

Demographic data	*n*	%
Patient number (*n*)	200	100
Female/ male (*n*)	118/82	59/41
Age (mean ± *SD*/ median) (years)	62.68 ± 14.31/64.37	-
Smoking habits (*n*)	14	7
History of periodontitis (*n*)	112	56
Smoking habits + History of periodontitis (*n*)	11	5.5
Number of implants per patients	1 Implant: 55	27.5
	2 Implants: 43	21.5
	3 Implants: 26	13
	4 Implants: 30	15
	5 Implants: 10	5
	6 Implants: 14	7
	7 Implants: 7	3.5
	8 implants: 6	3
	9 Implants: 3	1.5
	10 Implants: 6	3
Implant site characteristics		
Implant sites (*n*)	657	100
Implant age months (min–max/median)	1–317/112.37 ± 77.22	-
Implant age groups: 1–24/24–60/ >60 months (*n*)	57/147/453	8.68/22.37/68.95
Location Upper Jaw: anterior/posterior segment (*n*)	115/266	17.50/40.49
Location Lower Jaw: anterior/posterior segment (*n*)	66/210	10.05/31.96
Keratinized mucosa: >2 mm/<2mm (*n*)	505/152	76.86/23.14
Mucosal recession: presence/absence (*n*)	182/475	27.70/72.30
Suppuration: presence/absence (*n*)	23/634	3.50/96.50
Implant Diameter: 3.5/4.5/5.5 mm (*n*)	531/ 119/ 7	80.82/ 18.11/ 1.07
Implant length: 6.6/ 8/ 9.5/ 11/ 14/ 17 mm (*n*)	4/ 30/ 114/ 406/ 97/ 6	0.61/ 4.57/ 17.35/ 61.80/ 14.76/ 0.91
Prosthesis: fixed/ removable (*n*)	492/ 165	74.89/ 25.115
Bone augmentation: none/ one-stage/two-stage	357/ 300/ 0	54.34/ 45.66/ 0
Soft tissue augmentation: no/CTG[a]/FGG[b]/CTG + FGG	576/ 30/ 49/ 2	87.67/ 4.57/ 7.465/ 0.30

Abbreviations: *n*, number; *SD*, standard deviation; *n*, nu

[a]CTG, connective tissue graft.

[b]FGG, free gingival graft.

TABLE 2 Clinical parameters (mean ± *SD* and median): Patient (*n* = 200) and Implant (*n* = 657) levels

	Patient level		Implant level	*p* value
Plaque index	0.41 ± 0.37	0.33	0.48 ± 0.42	0.33
Bleeding on probing (%)	31 ± 26	25	27.09 ± 31.26	16.60
Probing depth (mm)	2.73 ± 0.79	2.81	2.87 ± 0.85	2.83
Keratinized mucosa (mm)	2.93 ± 1.4	2.85	2.91 ± 1.73	3.0
Radiographic bone loss (mm)	0.7 ± 1.52	0.44	0.44 ± 1.18	0.19
Mucosal recession (mm)	0.14 ± 0.25	0	0.16 ± 0.35	0

Abbreviations: *n*, number; mm, millimeter.

At peri-implant mucositis sites, the frequency of BOP scores referring to the number of sites within each implant ranged from 17% to 33%, while a higher range was noted at peri-implantitis sites (33%–100%; Table 4). Healthy implant sites and sites presenting peri-implant mucositis were most frequently associated with PD values of 1–3 mm, whereas the majority of the implants diagnosed with peri-implantitis (55%) exhibited PD values of 4–6 mm. A PD value of more than 6 mm was only noted in one of the implants diagnosed with peri-implantitis (Table 5).

3.3 | Factors associated with peri-implant health/diseases

Cross-tabulations of selected independent variables and diagnosis at the patient and implant levels are summarized in Tables 6 and Table 7.

TABLE 3 Frequency distribution of healthy and diseased sites: Patient (n = 200) and Implant (n = 657) levels

	Patient level	Implant level
Healthy	37	197
Peri-implant Mucositis	133	411
Peri-implantitis	30	49

Abbreviation: n, number.

3.4 | Patient-related factors

Patient-level regression analysis pointed toward a significant association between the events "peri-implantitis" and "history of periodontitis" (p = .003; OR = 5.33; 95% CI: 0.223–0.946). No association was noted among the events "healthy" and "peri-implant mucositis" and the investigated patient-related factors.

4 | DISCUSSION

The present cross-sectional analysis demonstrated that peri-implant diseases affected the majority of the enrolled patients having two-piece, platform-switched implant system placed at a subcrestal (1–3 mm) position (81.5%) after a median function time of 9.36 years. Specifically, 66.5% of the patients were diagnosed with peri-implant mucositis, and the remaining 15.5% presented signs of peri-implantitis. The corresponding values at the implant-level analysis amounted to 62.6% and 7.5%, respectively.

The noted prevalence of peri-implant diseases was, however, comparable to the results of one previous cross-sectional study following a similar investigation protocol on one tube-in-tube connection implant system (Schwarz et al., 2017a). In particular, after a medium follow-up period of 23 months, an investigation of 238 patients with a total of 512 implants revealed peri-implant tissue health in 44.5% of the subjects. The remaining 55.5% were diagnosed with peri-implant tissue diseases. Out of this latter group, 41.6% of the

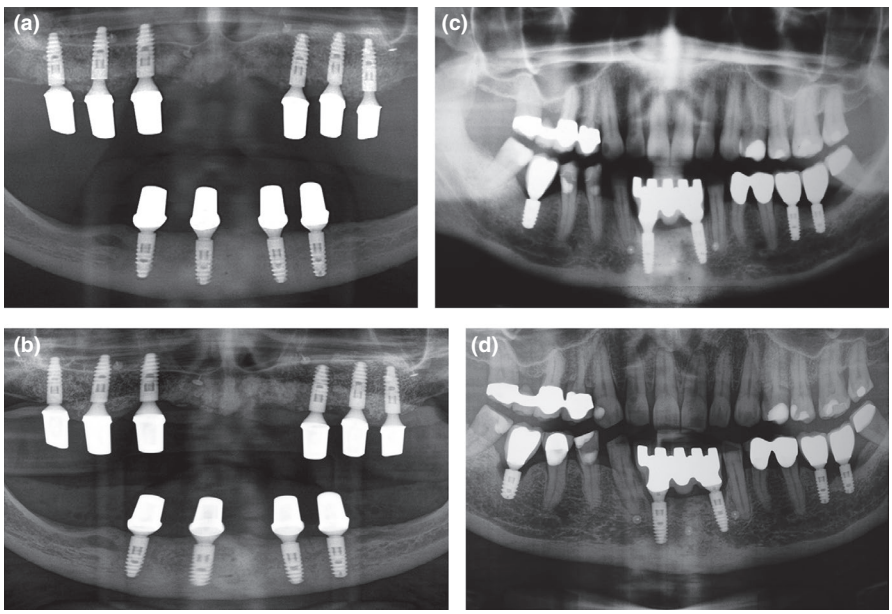

FIGURE 1 (a) Baseline panoramic radiograph taken following the prostheses installation; (b) panoramic radiograph taken after 7 years after prostheses installation showing no marginal bone loss at implants; (c) baseline panoramic radiograph taken following the prosthesis installation region 046; (d) panoramic radiograph taken 10 years depicting marginal bone loss at implant 046

TABLE 4 Frequency distribution of BOP scores at diseased implant sites (n = 460)

	17%	33%	50%	67%	83%	100%
Peri-implant Mucositis	114	74	86	55	44	38
Peri-implantitis	5	14	9	7	3	11

Abbreviations: BOP, bleeding on probing; n, number.

subjects were diagnosed with peri-implant mucositis and 13.9% were diagnosed with peri-implantitis. At the implant level, this corresponded to 35.6% and 7.6%, respectively (Schwarz et al., 2017a).

Similar disease frequencies were likewise indicated in previous cross-sectional investigations, even when they included various implant systems. In particular, the rate of the patients exhibiting diseased implants varied between 53.3% (Derks et al., 2016) and 70% (Vignoletti et al., 2019). Out of these patients, the majority (38.3% (Derks et al., 2016) to 35% (Vignoletti et al., 2019)) were diagnosed with peri-implant mucositis, and the remaining patients showed signs of peri-implantitis (14.5% (Derks et al., 2016) to 35% (Vignoletti et al., 2019)). A noteworthy finding of the present analysis is a higher prevalence of peri-implant mucositis compared to the aforementioned investigations. In this context, it is important to underline that the reported prevalence of the disease is highly influenced by the definitions used to define the pathology (Derks & Tomasi, 2015). In fact, a recent retrospective analysis of 274 implants of the same brand as those used for the present study revealed a high variation in the prevalence of either peri-implant mucositis (25.5 to 48.2%) or peri-implantitis (6.9 to 15%) after 17 to 23 years, depending on the case definitions applied (Krebs et al., 2019). Specifically, when peri-implant mucositis was defined as bone loss <1.5 mm along with BOP, the prevalence amounted to 40.1%, but it decreased to 15.5% once the criteria of a PD value of <4 mm was added. Peri-implantitis was diagnosed for 29.6% of the implants when a PD ≥ 4 mm along with BOP was considered, but it decreased to 15% once the threshold for bone loss was set at ≥1.5 (Krebs et al., 2019). Accordingly, variations in the case definitions applied complicate a direct comparison of the present data with those reported in the latter study on the same implant type. Nonetheless, the frequency of peri-implant mucositis and peri-implantitis detected in the present analysis is within the range to those, reported in the former systematic reviews and meta-analysis where various disease definitions were pooled (Atieh et al., 2013; Zitzmann & Berglundh, 2008).

TABLE 5 Frequency distribution of deepest PD values at healthy and diseases implant sites ($n = 657$)

	Healthy	Peri-implant Mucositis	Peri-implantitis
1–3 mm	175	310	21
4–6 mm	21	99	27
>6 mm	1	2	1

Abbreviations: PD,probing depth; *n*, number.

It is well documented that the insertion of endosseous dental implants is followed by a physiological bone remodeling, which inevitably occurs during the establishment of the peri-implant soft-tissue complex (Schwarz et al., 2013; Tomasi et al., 2014). Considerable evidence suggests that the depth of the implant insertion is one of the critical factors that defines the extent of the initial bone remodeling (Schwarz et al., 2014). Data from preclinical and clinical studies have indicated that implant placement below the crestal bone level is associated with a higher initial marginal bone loss than epi- or supracrestal implant positions (Hermann et al., 2000; Koutouzis et al., 2014; Schwarz et al., 2008; Vervaeke et al., 2018). Despite a more pronounced bone remodeling, the subcrestal implant position resulted in bone being located above the implant shoulder, while a crestal bone resorption of 0.5–1.0 mm was noted for implants placed in an epicrestal position (Degidi

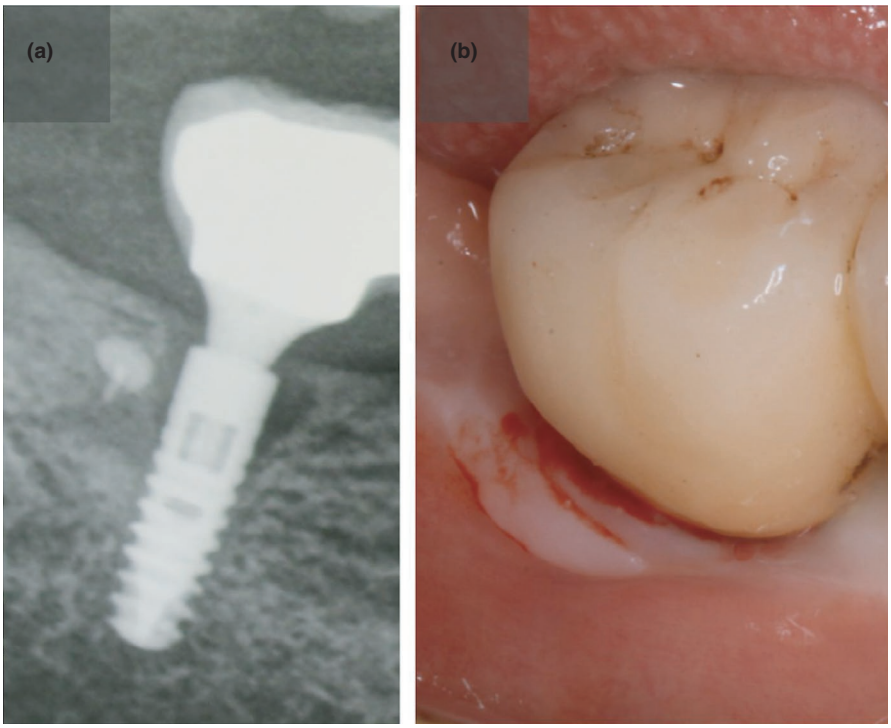

FIGURE 2 Clinical outcomes noted during data assessment. (a) Radiograph taken after the 6-year follow-up depicting marginal bone loss at implant 047 (b) along with signs of soft tissue inflammation. According to the given case definitions, implant 047 was diagnosed with peri-implantitis

et al., 2011). As previous clinical data have clearly shown that residual bone defects around the implants increase the risk of peri-implant tissue inflammation, subcrestal implant placement may be considered a preventive measure to decrease the likelihood of the exposure of the roughened implant parts (Schwarz et al., 2017b; Schwarz et al., 2012).

On the other hand, deep implant placement was shown to increase mucosal tunnel depth, which subsequently leads to the increased submucosal position of the implant–prosthesis interface (Chan et al., 2019). As such, the submucosal positioning of the crown restoration was shown to interfere with the mucosal seal around the transmucosal part of the implant, thereby promoting the onset of peri-implant tissue inflammation (Derks et al., 2016). In this context, it might be speculated that the higher frequency of peri-implant mucositis noted in the present analysis might be at least partially explained by the increased mucosal tunnel around subcrestally placed implants. Moreover, worth mentioning is the fact that a deeper peri-implant mucosal tunnel was found to be correlated with a delayed tissue response to the therapy of experimentally induced peri-implant mucositis (Chan et al., 2019). This latter finding leads to the assumption that subcrestal implant insertion may be a modifying factor for the treatment outcomes of peri-implant tissue infections (Chan et al., 2019).

TABLE 6 Implant level ($n = 657$) cross-tabulations between diagnosis and plaque index values, implant functioning time, hard tissue augmentation procedures, keratinized mucosa height, type of prosthesis, mucosal recession, soft tissue augmentation

Plaque index values	Healthy	Peri-implant Mucositis	Peri-implantitis
Plaque index values			
<1	171	302	39
>1	26	109	10
Implant functioning time			
1–24 months	25	30	2
24–60 months	40	60	17
>60 months	132	291	30
Augmentation (hard tissue)			
None	110	214	33
One-stage	87	197	16
Two-stage	0	0	0
Keratinized mucosa			
<2 mm	36	101	15
>2 mm	161	310	34
Prosthetic rehabilitation			
Fixed	150	313	29
Removable	47	98	20
Mucosal recession			
0 mm	154	287	34
>0 mm	43	124	15
Augmentation (soft tissue)			
No grafting	164	373	39
CTG[a]	15	14	1
FGG[b]	18	22	9
CTG + FGG	1	1	0

Abbreviation: *n*-number.

[a]CTG–connective tissue graft.

[b]FGG–free gingival graft.

On the contrary, implants located in the posterior regions as well as implants inserted in patients with a history of periodontitis exhibited higher odds ratios for peri-implantitis (OR, 0.46 and 5.33, respectively). This is in agreement with previous investigations in which patients with a history of periodontitis exhibited a higher risk for peri-implantitis (Derks et al., 2016, Vignoletti et al., 2019). The opposing data, nevertheless, failed to detect a correlation between the patients' periodontal statuses and peri-implantitis, which could be at least partly explained by the fact that the aforementioned study was based on a relatively small patient subset with a history of periodontitis enrolled in regular maintenance program (Schwarz et al., 2017a). Regarding smoking status, the current analysis failed to associate smoking with peri-implant diseases, though previous contradictory findings have pointed toward a higher risk of peri-implantitis among smokers (OR, 2.09–2.679) (Schwarz et al., 2017a,b; Vignoletti et al., 2019).

The present analysis pointed toward similar distribution of the implants in different subgroups with regard to the presence of absence of lateral bone augmentation and amount of KM (i.e., <2 mm or > 2 mm), whereas previous findings revealed a link between simultaneous bone grafting procedures, reduced KM height (< 1 mm) and an increased risk of peri-implantitis (Canullo et al., 2016a,b; Vignoletti et al., 2019). The latter correlation might be attributed to the fact that the absence or a reduced KM width may negatively affect self-performed oral hygiene measures, which subsequently increases the likelihood of soft-tissue inflammation (Berglundh et al., 2018). Furthermore, similar implant distribution in different subgroups based on the diagnosis was noted with respect to the type of prosthetic rehabilitation thus basically corroborates the results of a recent systematic review, which indicated a comparable

TABLE 7 Patient level ($n = 200$) cross-tabulation of patient-related risk factors and diagnosis

	Healthy	Peri-implant Mucositis	Peri-implantitis	Odds ratio	Confidence Interval 95%	*p*-value
Smoking	3	8	3	0.16	0.005–0.049	.843
History of periodontitis	15	73	24	5.33	0.223–0.946	.003

Abbreviation: *n*, number.

prevalence of peri-implant tissue diseases for fixed and removable restorations (Ramanauskaite et al., 2020). In this context, it must be noted that 28% of the included implants presented with soft-tissue mucosal recession (22% healthy, 30% peri-implant mucositis, and 31% peri-implantitis). To the authors' best knowledge, this is the first study reporting soft-tissue recession in the presence of peri-implant diseases. Nevertheless, the present data point toward no association between soft-tissue recession and peri-implant tissue health status.

All patients in the present cross-sectional analysis were treated and followed in one university center and may, therefore, not be regarded as a random patient sample. Furthermore, all of the patient were enrolled in the regular supportive therapy regime, which might be one of the contributing factor leading to underestimation of the disease frequency. It also needs to be noted that clinical parameters were assessed while keeping the prosthetic reconstruction in place, thus, a convergent abutment profile as well as prostheses design might have influenced the accuracy of the PD values. Another limitation of the present analysis concerns the assessment of periodontal disease based on the PSI, which has been shown to have limited reliability in the diagnosis of patients' periodontal health (Ziebolz et al., 2011). Ultimately, a limited number of factors included into the analysis and the absence of multivariate analysis may have further influenced the results of the present study.

Within the limitations of the present study, it was concluded that peri-implant diseases were a common finding around subcrestally placed implants.

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CONFLICT OF INTEREST

All authors stated explicitly that there are no conflicts of interest related to this article.

AUTHOR CONTRIBUTION

Karina Obreja contributed to the data acquisition, interpretation and manuscript writing; Ausra Ramanauskaite contributed to the data acquisition, interpretation and analysis, and manuscript writing; Amira Begic contributed to the data acquisition, interpretation and analysis; Maria Elisa Galarraga contributed to the data acquisition; Puria Parvini contributed to the data acquisition; Robert Sader made substantial contribution to the interpretation of data and manuscript critical revision; Frank Schwarz contributed to the idea generation, conception and interpretation of data, manuscript writing and critical revision.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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