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ORIGINAL ARTICLE

Prevalence, risk indicators, and clinical characteristics of peri-implant mucositis and peri-implantitis for an internal conical connection implant system: A multicenter cross-sectional study

Karin Apaza-Bedoya[1] | **Maria Elisa Galarraga-Vinueza**[2,3] | **Bruna Barbosa Correa**[1] | **Frank Schwarz**[4] | **Marco Aurélio Bianchini**[1] | **Cesar Augusto Magalhães Benfatti**[1]

[1]Department of Dentistry, Center for Education and Research on Dental Implants (CEPID), Federal University of Santa Catarina (UFSC), Florianopolis, Brazil

[2]School of Dentistry, Universidad de las Americas (UDLA), Quito, Ecuador

[3]Department of Prosthodontics, Tufts University School of Dental Medicine, Boston, Massachusetts, USA

[4]Department of Oral Surgery and Implantology, Carolinum, Johann Wolfgang Goethe-University Frankfurt, Frankfurt, Germany

Correspondence
Maria Elisa Galarraga-Vinueza, Department of Prosthodontics, Tufts University School of Dental Medicine, 1 Kneeland St., Boston, MA 02111, USA.
Email: maria.galarraga_vinueza@tufts.edu

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Abstract

Background: Peri-implant disease prevalence is associated with a multifactorial etiology and distinct clinical characteristics of inflammation.

Methods: The present study aimed to assess the prevalence of peri-implant diseases, identify related risk indicators, and associate specific clinical characteristics to peri-implant biological complications in the medium term. Peri-implant diseases were classified according to established case criteria. Patients' data, implant and/or prosthetic features, and maintenance records were collected. Clinical characteristics such as bleeding on probing (BOP), suppuration (SUPP), keratinized mucosa (KM), probing depth (PD), marginal recession (MR), and modified plaque index (mPI) were recorded.

Results: Ninety-nine patients with 266 implants with a mean functional duration of 30.26 months were evaluated. Peri-implant mucositis and peri-implantitis prevalence totaled to 49.5% and 15.15% (patient level), respectively. Peri-implant mucositis was associated with osteoporosis (odds ratio [OR] 6.09), age (OR 0.97), diabetes mellitus (OR 3.09), cemented-retained prosthesis (OR 3.81), and partial prosthesis (OR 2.21). Peri-implantitis was associated with osteoporosis (OR 7.74) and periodontitis (OR 2.74), cemented prosthesis (OR 10.12), partial and full arch prostheses (OR 12.35 and 19.86), implant diameter (OR 3.64), abutment transmucosal height (OR 3.39), and hygiene difficulty (OR 3.14). Furthermore, mPI score 3 (OR 3.27) and PD scores (OR 1.64) were associated with peri-implant mucositis, while mPI score 3 (OR 16.42), KM (OR 1.53), PD (OR 1.81), MR (OR 2.61), and the relationship between KM and PD (OR 0.63) were associated with peri-implantitis.

Conclusion: In the medium term, peri-implant diseases were correlated with factors inherent to the patient's conditions, presurgical treatment plan, and hygiene maintenance care. The knowledge of the mentioned factors and featured clinical characteristics can be crucial for disease prevention and establishment of a superior implant therapy prognosis.

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KEYWORDS
dental implant-abutment design, dental implants, epidemiology, peri-implantitis

1 | INTRODUCTION

Peri-implant diseases are common inflammatory entities that affect the integrity of soft and hard peri-implant tissues.[1,2] The aforementioned diseases are usually associated with biofilm accumulation and characterized by clinical signs of inflammation.[1,3] Peri-implant mucositis might progress to peri-implantitis when the inflammatory response residing in the soft tissue compartment affects the underlying peri-implant bone, and consequently progressive marginal bone loss (MBL) is triggered.[4]

Contemporary epidemiological studies have shown that peri-implant mucositis and peri-implantitis prevalence ranges from 27% to 63% and from 7% to 28%, respectively.[5–9] Furthermore, diverse patient- and implant-related features, such as presence and/or history of periodontal disease, poor implant maintenance, and plaque accumulation at implant surfaces have been defined as risk indicators for peri-implant diseases.[1,9,10] Nevertheless, other factors such as smoking habits, diabetes mellitus, osteoporosis, hygienic factors, prosthesis design, and other implant-related features have been studied in several epidemiological studies but have not yet been defined as established risk indicators for peri-implant diseases.[1,9,10]

Clinical signs of peri-implant mucositis are characterized as redness, mucosal enlargement, and bleeding on probing (BOP) with/without suppuration (SUPP).[11] Moreover, peri-implantitis is associated with the aforementioned characteristics with higher probing depth (PD) values and progressive MBL.[1,12,13] The association between clinical parameters and peri-implant diseases has been evaluated in earlier epidemiologic studies with the aim of detecting characteristic features of peri-implant diseased sites.[14–17] Nevertheless, current evidence is not robust toward the possible effect of peri-implant keratinized mucosa (KM), attached mucosa, and marginal recession (MR) as possible risk indicators of peri-implant diseases.[1,18]

The primary aim of this multicenter cross-sectional study is to evaluate the prevalence of peri-implant mucositis and peri-implantitis for an internal conical connection implant system in a Brazilian population. Secondary outcomes include the identification of risk indicators and the association of specific clinical characteristics to peri-implant diseases.

2 | MATERIALS AND METHODS

2.1 | Study design

This cross-sectional study was approved by the ethics committee on human studies (CAAE14643519.3.1001.0121) and involved three Brazilian postgraduate centers in oral implantology: (1) Center for Education and Research on Dental Implants at the Federal University of Santa Catarina, Florianopolis, (2) Foundation for Scientific and Technological Development of Dentistry at the University of Sao Paulo, and (3) University Paulista of São Paulo. The study was conducted from September 2019 to July 2020 based on the Helsinki Declaration of 1975 (revised in 2008), and its reports follow the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines for observational clinical studies.[19]

2.2 | Sample selection

The medical records of subjects with fixed prostheses supported on two-piece conical connection titanium implants* with a functional duration of at least 1 year were screened. Subjects were contacted and invited to participate. At least three contact attempts were made.

The exclusion criteria considered patients who (i) were taking medications that affect bone turnover (i.e., bisphosphonates and denosumab), (ii) were pregnant/breastfeeding women, (iii) lost their implants during the follow-up period and could not be re-evaluated, (iv) had an implant that underwent peri-implantitis surgical treatment, (v) had unloaded implants (absence of prosthetic component), (vi) had implants with prostheses that do not allow correct access for clinical assessment, and (vii) had incomplete records.

After the invited participants accepted and signed an informed consent, they were subjected to a clinical and radiographical evaluations.

* Implacil De Bortoli, Sao Paulo, Brazil.

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2.3 | Data collection

The following data were extracted from the patients' dental records and confirmed in the clinical examination:

1. Patient-related factors: age, sex, heart disease, hypertension, uncontrolled diabetes mellitus (glycosylated hemoglobin [HbA1c] > 7), osteoporosis, history of periodontitis (current or treated) evaluated from the patient record based on a periodontal screening index (PSI) score value ≥ 3, presence of wear facets, and smoking habits (>1 cigarette/day).
2. Implant- and/or prosthesis-related factors: region, implant length and diameter, abutment length and diameter, retention type, prosthesis type, screw complications (history or presence of loosening or fracture), implant placement time, implant loading time, radiographic presence of gap between prosthesis and abutment, and follow-up time from implant and prosthesis installation.
3. Maintenance-/hygiene-related factors: professional cleaning (at least one per year); hygiene discomfort and difficulty (classified as low, medium, and high); hygiene routine (only manual brushing or use of other additional methods such as interdental brush, dental floss, or water floss at least once a day).

2.4 | Clinical parameters

The following clinical parameters were assessed:

-BOP: absent or present as line or drop after 30 s.
-SUPP: absent or present after palpation or probing.
-Modified plaque index (mPI): Scores 0–3.[20]
-KM: in millimeter; considering the mucogingival line as the apical limit.
-PD: in millimeter; peri-implant pocket probing depth.
-MR: in millimeter; absence of recession was considered as zero. The transmucosal collar of the abutment was considered as the cervical limit.
-Relationship between KM and PD (KM–PD): calculated by subtracting PD values from KM.

To perform the clinical evaluation, a plastic periodontal probe[†] was used. The clinical parameters mPI, BOP, SUPP, PD, and MR were assessed at six implant sites (distobuccal, midbuccal and mesiobuccal and distolingual, midlingual and mesiolingual). KM was obtained only at the three buccal implant aspects. BOP and SUPP were considered as "present" when at least one site was positive. For the other parameters, the "worst" value was considered for analysis. That is, for mPI, PD, and MR, the highest value was contemplated, and for KM and KM–PD the lowest value was considered.

2.5 | Radiographic assessment

Digital periapical radiographs[‡] were taken using the parallel technique at the time of clinical examination of this study. Radiological measurements were performed by one calibrated examiner. The analysis of measurements was performed based on the known implant height using an image processing software.[21,22] [§] Hence, MBL was measured as the distances in millimeter between the shoulder of the implant and the first bone-to-implant contact. Measurements performed apically to the implant shoulder were considered as negative values. Each measurement was performed three times, and an average was calculated for higher accuracy. The lowest MBL value, either mesial or distal, was considered to perform the diagnosis.

2.6 | Peri-implant case definitions

Peri-implant diseases were assessed according to the 2017 World Workshop on the Classification of Periodontal and Peri-implant Diseases and Conditions[12] for epidemiologic studies where radiographic and clinical information from the time point when the suprastructure was placed was not available[23]: (1) Peri-implant health was determined as the absence of clinical signs of inflammation and profuse BOP; (2) peri-implant mucositis was diagnosed when soft tissues presented signs of inflammation, presence of profuse BOP and/or SUPP, and absence of radiographic MBL (i.e., <3 mm, interproximal distance from implant platform to the first bone implant contact); and (3) peri-implantitis was diagnosed as a combination of BOP and radiographic MBL ≥ 3 mm at either medial or distal sites[12].

2.7 | Statistical analysis

The sample size was calculated based on the proportion of an infinite population, where the precision was set at 5%, confidence level at 80%, and the prevalence of peri-implantitis was 16.4%[10]. The minimal sample size estimated was 90 patients (OpenEpi, Atlanta, Georgia, USA).

[†] Colorvue #12; Hu-Friedy Inc., Chicago, Illinois, USA.

[‡] EVO; Micro Imagem, Indaiatuba, Brazil.

[§] Image J v.2.0.; National Institutes of Health, Bethesda, Maryland, USA.

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The prevalence of health and peri-implant diseases were reported at implant and patient level (the implant with the most advanced clinical signs of disease was chosen).

Descriptive analyses and regression tests were performed considering implant level as the unit of assessment. Multinomial logistic regression was performed to examinate the effect of patient-, implant-, and maintenance-related indicators with the implant diagnoses using health as reference and $p < 0.05$ to indicate statistical significance. To verify multicollinearity of the independent variables, a tolerance of <0.1 and a variance inflation factor of >10 were considered. For the patient and implant-/prostheses-related factors, an adjusted regression model was performed ($p < 0.20$). To analyze the association of the use of additional methods to manual brushing with the diagnoses, the implants were separated into single and multiple prostheses. Pearson's chi-square or Fisher's exact test were used. Pairwise Z as post hoc test were performed if necessary to identify the subset that differs statistically.[24] p values were corrected by the Bonferroni method. To analyze the clinical parameters and their relationship with peri-implant diseases, multinomial logistic regression was performed ($p < 0.05$). All statistical analyses were carried out using SPSS version 21.0 (IBM Corp., Armonk, New York, USA).

To appraise the bivariate relationship between two clinical characteristics and its trends by diagnoses, a scatterplot matrix was constructed using Seaborn library in Python software (Python 3.8.5, Python Software Foundation, Wilmington, Delaware, USA).

3 | RESULTS

Ninety-nine patients (44 men and 55 women) with 266 implants were included in the present cross-sectional study after contemplating the exclusion criteria. During follow-up, only five implants were lost in the present population. The patients' mean age was 55.20 ± 10.62 years (range 31–77 years, median 56 years), and the average implant function time was 30.26 ± 17.86 months (2.52 years) (range 12–90 months, median 25 months). Overall, 10.1% of the patients had diabetes mellitus (7.89% of implants), 7.07% osteoporosis (5.64% of implants), 17.17% periodontitis (23.68% of implants), and 13.13% were smokers (13.53% of implants).

3.1 | Prevalence

At patient level, peri-implant mucositis and peri-implantitis prevalence totaled to 49.5% and 15.15%, respectively. At implant level, peri-implant mucositis and peri-implantitis prevalence was 42.86% and 11.65%, respectively. There were a total of five implant losses, representing a survival rate of 98.15% (implant level) for the present internal conical connection implant system.

Cross-tabulations of clinical parameters and MBL measurements with the diagnoses are summarized in Table 1. Multinomial logistic regression results are described in Table S1.

3.2 | Risk indicators

3.2.1 | Patient-related indicators

Osteoporosis was significantly associated with the development of both peri-implant diseases, being positively associated with peri-implant mucositis (odds ratio [OR] 6.086; CI, 1.336–27.723; $p = 0.020$) and peri-implantitis (OR 7.739; CI, 1.388–43.152; $p = 0.020$). Implants in older patients appeared less likely to be associated with peri-implant mucositis (OR 0.966; CI, 0.936–0.997; $p = 0.029$), and implants in patients with uncontrolled diabetes mellitus were more likely to be associated with peri-implant mucositis (OR 3.087; CI, 0.955–9.984; $p = 0.060$). Presence or history of periodontitis showed a positive and significant association to peri-implantitis (OR 2.736; CI, 1.112–6.735; $p = 0.029$), as shown in Table 2.

3.2.2 | Implant-related indicators

The implant prosthetic retention type showed an association with both peri-implant diseases; thus, cemented-retained prostheses were more likely to present peri-implant mucositis (OR 3.810; CI, 1.698–8.548; $p = 0.001$) and peri-implantitis (OR 10.119; CI, 2.430–42.145; $p = 0.001$). Partial prostheses displayed a higher association to peri-implant mucositis (OR 2.207; CI, 1.028–4.362; $p = 0.045$) and peri-implantitis (OR 12.348; CI, 2.717–56.123; $p = 0.001$) when compared to unitary prostheses. Total prostheses showed a higher association to peri-implantitis (OR 19.864; CI, 4.212–93.692; $p = 0.001$). In addition, peri-implantitis was positively associated with implants with a diameter >3.75 mm (OR 3.638; CI, 1.324–9.995; $p = 0.012$) and abutments presenting a transmucosal height ≤1.5 mm (OR 3.393; CI, 1.379–8.349; $p = 0.008$) (Table 2).

3.2.3 | Maintenance/hygiene-related indicators

The majority of the evaluated implants (71.80%) were cleaned only by manual brushing, showing higher association to peri-implant mucositis (OR 2.989; CI, 1.531–5.834;

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TABLE 1 Cross-tabulations of clinical and radiographic assessments with diagnoses at implant level.

	Healthy		Peri-implant mucositis		Peri-implantitis		Total	
Clinical parameters								
BOP (*n*, %)								
Absent	121	100%	3	2.63%	0	0%	124	46.62%
Present	0	0%	111	97.37%	31	100%	142	53.38%
SUPP (*n*, %)								
Absent	121	100%	102	89.47%	26	83.87%	249	93.61%
Present	0	0%	12	10.53%	5	16.13%	17	6.39%
mPI (*n*, %)								
0	53	43.80%	36	31.58%	6	19.35%	95	35.71%
1	30	24.79%	37	32.46%	5	16.13%	72	27.07%
2	24	19.83%	20	17.54%	3	9.68%	47	17.67%
3	14	11.57%	21	18.42%	17	54.84%	52	19.55%
KM (mm)								
Mean, SD	3.06 ± 1.89		3.11 ± 1.90		3.52 ± 1.67		3.14 ± 1.87	
PD (mm)								
Mean, SD	2.77 ± 1.19		3.79 ± 1.75		4.23 ± 2.05		3.38 ± 1.66	
PD (*n*, %)								
<6 mm	119	98.3%	96	84.2%	21	67.7%	236	88.7%
≥6 mm	2	1.7%	18	15.8%	10	32.3%	30	11.3%
MR (mm)								
Mean, SD	0.45 ± 0.80		0.52 ± 0.79		1.71 ± 1.58		0.63 ± 1.00	
KM–PD								
Mean, SD	0.40 ± 1.94		−0.23 ± 1.93		−0.84 ± 3.06		−0.2 ± 2.13	
Radiographic assessment								
MBL medial (mm)								
Mean, SD	−0.20 ± 1.65		−0.23 ± 1.32		−3.51 ± 1.05		−0.60 ± 1.79	
MBL distal (mm)								
Mean, SD	−0.26 ± 1.51		−0.40 ± 1.26		−3.56 ± 1.26		−0.71 ± 1.72	

Abbreviations: BOP, bleeding on probing; KM, keratinized mucosa; KM–PD, relationship between KM and PD; MBL, marginal bone loss; mPI, modified plaque index; MR, marginal recession; PD, probing depth; SUPP, suppuration.

$p = 0.001$) and peri-implantitis (OR 5.018; CI, 1.959–12.853; $p = 0.001$). Of the implants, 43.61% presented low difficulty for daily cleaning, 22.93% presented medium difficulty, and 33.46% high difficulty. The subset of implants with high hygiene difficulty presented a positive significant correlation to peri-implantitis compared to those with low difficulty (OR 3.144; CI 1.086–9.106; $p = 0.035$).

Considering unitary implant-supported prostheses ($n = 95$), the post hoc test revealed that the percentage of healthy implants was higher for those that used dental floss (86.54%, $p = 0.0138$). Meanwhile, for multiple implant-supported prostheses ($n = 171$), peri-implant mucositis was significantly higher when interdental brushes were not used ($p = 0.007$). Peri-implantitis was significantly higher when dental floss was not used ($p = 0.017$), and healthy diagnosis was higher at implants that were not cleaned with water flosser (52.2%, $p = 0.003$) (Figure 1).

3.3 | Clinical characteristics

A representation of clinical characteristics, central tendencies, and diagnoses is showed in Figure 2. The logistic regression model showed that plaque score 3 (mPI3) and higher PD values were positively associated with peri-implant mucositis (OR 3.27; CI, 1.338–8.004; $p = 0.009$; and OR 1.643; CI, 1.262–2.141; $p < 0.000$) and peri-implantitis (OR 1.525; CI, 3.682–73.233; $p < 0.000$; and OR 1.803; CI, 1.201–2.706; $p = 0.004$). Additionally, peri-implantitis was associated with higher MR values (OR 2.612; CI, 1.607–4.245; $p < 000$), KM values (OR 1.525; CI, 1.016–2.289;

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TABLE 2 Risk indicators significantly associated with peri-implant diseases (adjusted regression at implant level).

Peri-implant mucositis			
	OR	**95% CI**	***p* value**
Age	0.966	(0.936–0.997)	0.029
Diabetes mellitus			
No	3.087	(0.955–9.984)	0.060
Yes	–	–	–
Osteoporosis			
No	–	–	–
Yes	6.086	(1.336–27.723)	0.020
Retention type			
Cemented	3.810	(1.698–8.548)	0.001
Screwed	–	–	–
Prostheses type			
Unitary	–	–	–
Partial	2.207	(1.028–4.362)	0.045
Peri-implantitis			
	OR	**95% CI**	***p* value**
Osteoporosis			
No	–	–	–
Yes	7.739	(1.388–43.152)	0.020
Periodontal disease			
No	–	–	–
Yes	2.736	(1.112–6.735)	0.029
Implant diameter			
≤3.75 mm	–	–	–
>3.75 mm	3.638	(1.324–9.995)	0.012
Abutment height			
≤1.5 mm	3.393	(1.379–8.349)	0.008
>1.5 mm	–	–	–
Retention type			
Cemented	10.119	(2.430–42.145)	0.001
Screwed	–	–	–
Prostheses type			
Unitary	–	–	–
Partial	12.348	(2.717–56.123)	0.001
Total	19.864	(4.212–93.692)	0.001

Abbreviation: OR, odds ratio.

$p = 0.042$), and lower scores of KM–PD (OR 0.634; CI, 0.431–70.933; $p = 0.021$).

The scatterplot matrix illustrates the trend toward peri-implant diagnoses based on the relationship between a duo of clinical characteristics (Figure 3). Thus, the matrix evidenced a tendency to peri-implantitis when crossing mPI3 with higher values of PD and MR (Figure 3b and c, column 1). Also, when higher PD scores were crossed with higher levels of mPI or MR and lower KM–PD scores, a tendency to peri-implantitis was observed (Figure 3b–d, column 1 with row b and column 3 with rows c & d, respectively). MR lower scores indicated a tendency to health. MR values appeared to be influenced to develop peri-implant mucositis by the effect of mPI, PD, and KM–PD scores (Figures 3c and 4d, column 1 with row c, column 3 with row c, and column 4 with row d, respectively). No marked trends were identified at the intersection of KM with other clinical parameters.

4 | DISCUSSION

The present study aimed to assess the prevalence of peri-implant diseases and identify possible risk indicators and clinical characteristics for an internal conical connection implant system on the medium term (i.e., 1 year > follow-up < 5 years). At the patient level, peri-implant mucositis and peri-implantitis prevalence totaled to 49.50% and 15.15%, respectively. Particular systemic, implant-related, prosthetic, and hygiene-related indicators were significantly associated with peri-implant diseases (Figure 4). Peri-implant mucositis and peri-implantitis were associated with high mPI and PD scores. Also, peri-implantitis was correlated with higher MR and lower KM–PD values. The scatterplot matrix revealed a tendency for plaque index and MR to have a stronger influence on the other clinical characteristics and consequently on peri-implant diagnoses.

Prevalence of peri-implant diseases in similar two-piece platform-switched conical connection implants were evaluated by other retrospective studies.[9,14] Krebs et al.[14] evaluated 274 implants applying various case definitions. Considering the most similar definition with the present study, they found a peri-implant mucositis prevalence of 43.8% (defined as MBL < 2.0 mm and + BOP) and 11.3% for peri-implantitis (BL ≥2.0 mm and + BOP), which are findings in accordance with our results. Moreover, Obreja et al.[9] evaluated in a larger population that peri-implant mucositis (BOP and/or SUPP, increased PD values, and absence of MBL) was present in 66.5% of the patients and peri-implantitis (BOP and/or SUPP, increased PD values, and MBL compared to the radiograph taken at final prosthesis placement) was present in 15.0% of the patients. The aforementioned higher mucositis prevalence rate may be explained by the longer follow-up time of the included implants (9.36 ± 6.44 years) and the different case definition used for the diagnoses when compared to the present study.

A consensus highlighted the limited existing evidence reporting on systemic conditions as possible risk factors/indicators for peri-implantitis.[1] The data of the present study significantly associated osteoporosis with both peri-implant diseases. Diabetes mellitus was also

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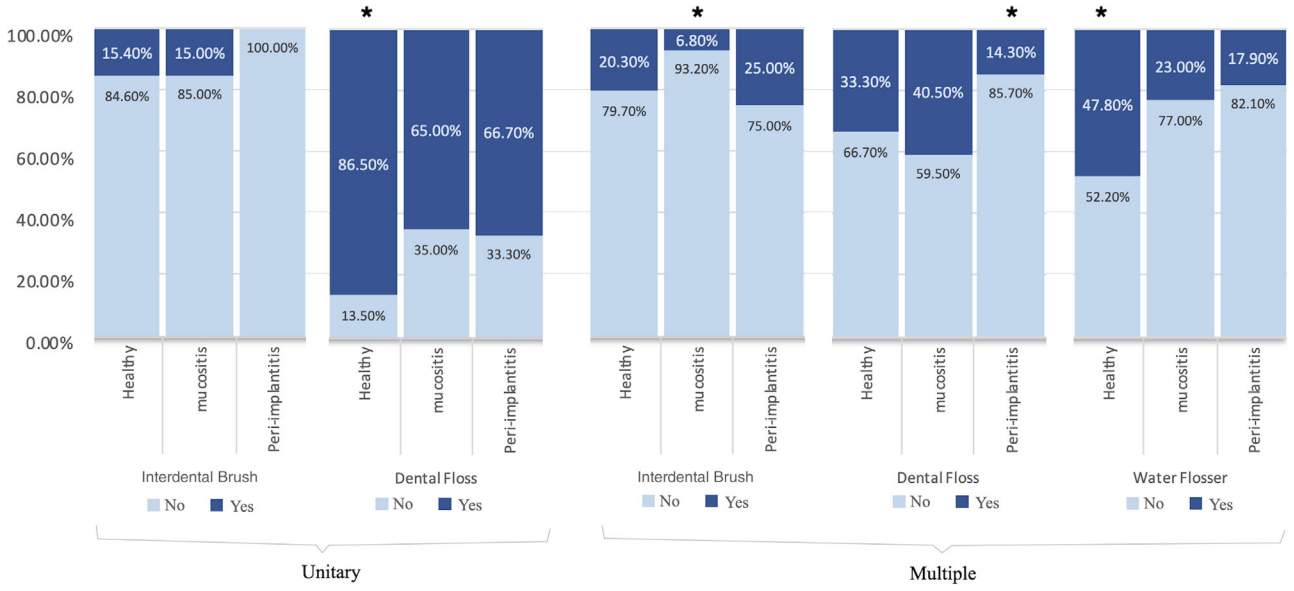

FIGURE 1 Diagram depicting the use of additional methods to manual brushing for unitary and multiple prostheses and its statistically significant differences ($p < 0.05$) among diagnoses (i.e., healthy, mucositis, and peri-implantitis). *$p < 0.05$.

significantly associated with peri-implant mucositis, but not with peri-implantitis. A recent systematic review did not find a significant association between peri-implantitis and osteoporosis; however, diabetes was identified as a risk factor (OR 2.5, 95% CI 1.4–4.5).[25] Moreover, Monje et al.[26] established that diabetes was associated with peri-implantitis, but not to peri-implant mucositis. The aforementioned outcomes differ from our results. This aspect could be related to the fact that the peri-implantitis case definition of the aforementioned study included lower MBL values (<2 mm) than those used for our diagnosis (MBL ≤ 3 mm); consequently, this subset of patients was reclassified as having peri-implant mucositis in the present study.

Furthermore, our analysis found a significant association between the presence or history of periodontal disease and peri-implantitis. Accordingly, Ferreira et al.[27] in a meta-analysis affirmed that history of periodontitis was a potential risk factor for the occurrence of peri-implantitis (OR 1.74). In further agreement with the presented results, recent findings from a study involving a similar implant system demonstrated a significant association between history of periodontitis and peri-implantitis (OR 5.33).[9] Still, future studies should differentiate the effect of history of periodontal disease versus active periodontal disease on the onset and progression of peri-implant diseases.

Considering risk indicators related to prosthetic features, our data showed that cemented-retained prostheses are associated with both peri-implant diseases' prevalence, which is in accordance with earlier studies reporting similar associations.[7,10,28] In fact, cement residues at the implant fixture could provoke a pathological foreign body reaction, which is a clinical implication that should be considered when deciding on the most appropriate prosthetic retention.[28] While multiple partial prostheses have possibly been associated with being a risk indicator for peri-implant mucositis and peri-implantitis, full arch prostheses have been associated with peri-implantitis prevalence. Similar results have been also reported by other clinical studies with longer follow-up.[7,29] Likewise, Dalago et al.[10] also associated full-arch prostheses with peri-implantitis; however, they failed in associating multiple partial prostheses with peri-implant diseases. Full-arch prostheses have artificial gums, which is a feature that possibly complicates hygiene and cleaning procedures, consequently provoking the accumulation of biofilm, which is one of the main etiological factors for peri-implant diseases.[1,4,22]

Moreover, low-rise transmucosal abutment height (≤1.5 mm) was significantly associated with peri-implantitis prevalence. In fact, this prosthetic feature shortens the distance between the restoration contour and the subjacent peri-implant bone. Therefore, an invasion of the peri-implant transmucosal biological space might occur and provoke an inflammatory osteolytic reaction. Accordingly, a systematic review concluded that bone-level implants with a transmucosal height greater than 2 mm presented reduced MBL during the first year following abutment connection and for longer post-loading periods.[30] The aforementioned aspect has important clinical implications for the proper selection of abutment transmucosal height and for considering the possible need of a soft tissue graft to increase the height,

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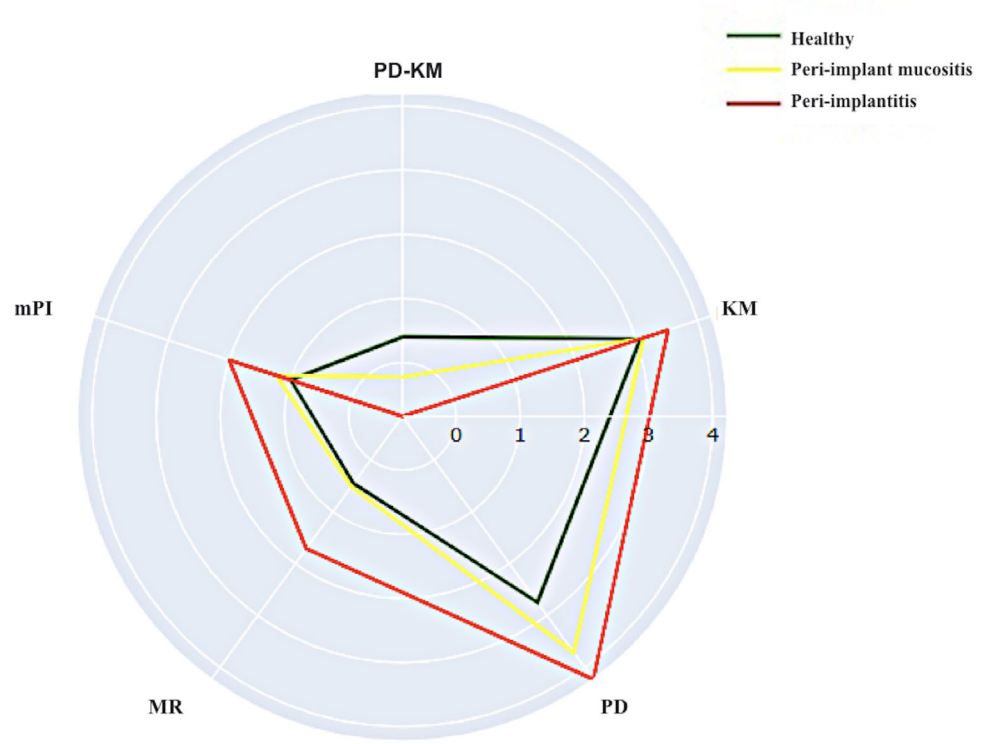

FIGURE 2 Clinical characteristics and peri-implant conditions at implant level. Lines representing diagnoses were drawn according to the mean of the characteristics. As the radius of the circle increases, the value also increases. Note that peri-implantitis (red line) is marked by highest values of mPI, MR, PD, and KM and lowest value of KM–PD. KM, keratinized mucosa; KM–PD, relationship between KM and PD; mPI, modified plaque index; MR, marginal recession; PD, probing depth.

thickness, and width of the peri-implant mucosa before crown delivery.

Greater implant diameters (>3.75 mm) were also associated with peri-implantitis, this finding could be explained from the assumption that larger diameters may provoke diminished thickness at buccal and lingual bone walls. Monje et al.[31] previously established that when the peri-implant buccal bone wall is <1.5 mm, a higher physiologic and pathologic bone loss can be expected around dental implants; however, the results of the present study cannot confirm this assumption since buccal bone thickness was not measured.

Regarding risk indicators related to peri-implant maintenance, our data associated peri-implantitis prevalence with high hygiene difficulty, which can be related to various features such as implant/prosthetic characteristics or patient cleaning skills.[32] In fact, poor plaque control skills have been listed as a possible risk indicator for both peri-implant diseases.[1,33] The present study revealed that the exclusive use of manual toothbrushes was associated with the prevalence of both peri-implant diseases, which is in accordance with a previous study performed in an Australian population.[34] Moreover, the use of water flossers was negatively associated with a healthy peri-implant status. This finding could be explained by the fact that water flossers are generally used by subjects with full-arch prostheses where the artificial gum may limit access for cleaning., Maintenance and appropriate hygiene seem to be crucial for the long-term prognosis of dental implant therapy.

Correlations between the diagnoses and BOP, SUPP, or MBL were not analyzed as they were part of diagnostic criteria. However, it is worth mentioning that BOP was present at the majority of the evaluated implants (53.38%), as previous studies also reported.[14,15,35] SUPP was observed in just 6.39% of the evaluated implants (10.53% for mucositis and 16.13% for peri-implantitis). However, some studies associated SUPP with peri-implantitis solely[16,36] and have established SUPP as an indicator of progressive MBL.[17]

A pre-established PD value as a diagnostic criterion in the classification of peri-implant diseases is still a controversial and debated aspect.[22,37,38] However, our data showed that higher PD values were significantly associated with both peri-implant diseases, suggesting that higher PD may disrupt the "barrier function" of peri-implant soft tissues around conical connection implants, which could trigger the progression of peri-implant diseases.[15,16]

Peri-implantitis has been defined as a plaque-associated inflammatory condition around dental implants that induces progressive peri-implant bone loss.[12] Even

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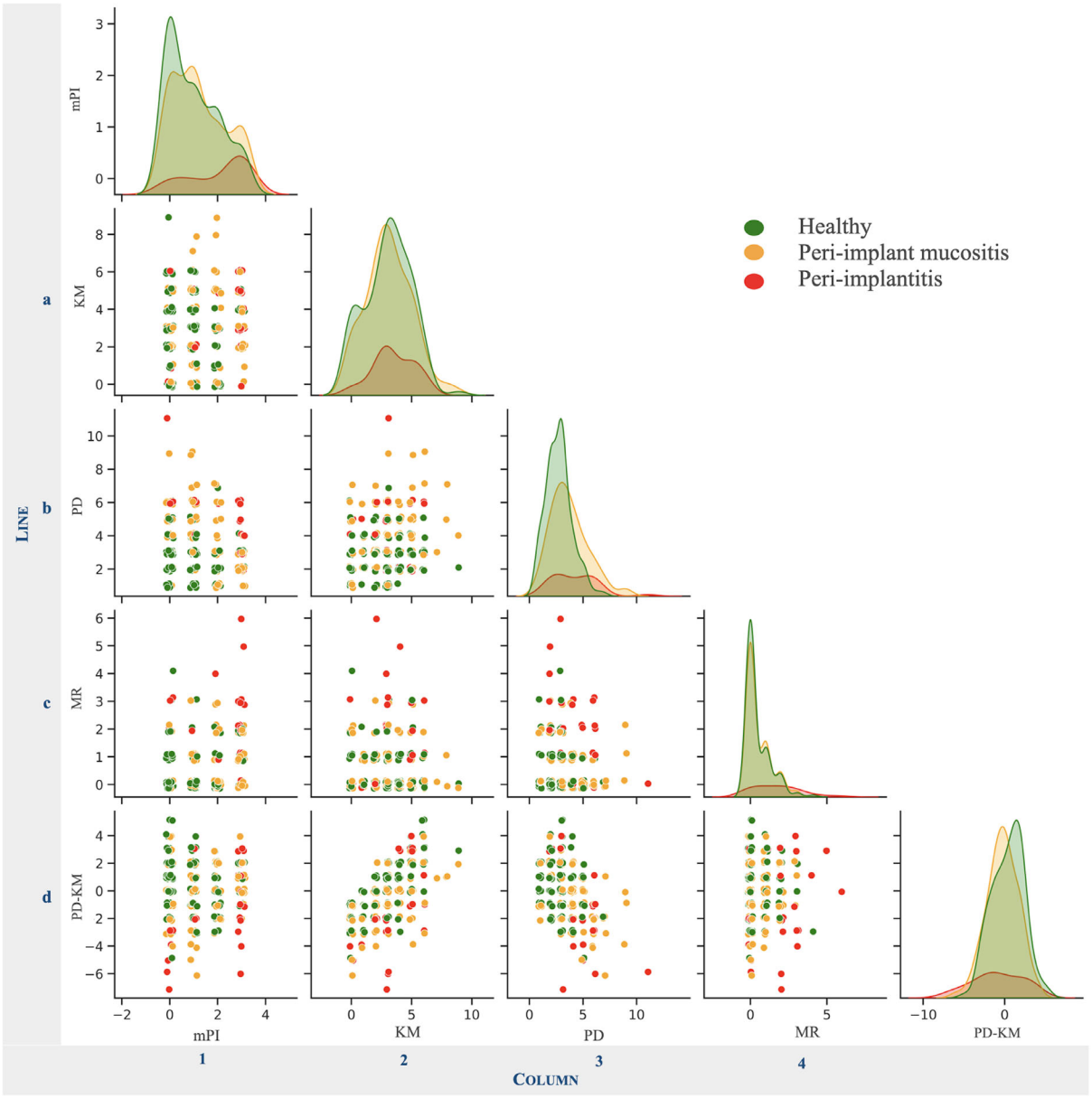

FIGURE 3 Scatterplot showing pairwise relationships between clinical characteristics in diagnosis datasets. Data for different diagnoses are represented by different colors (healthy, green—peri-implant mucositis—yellow, peri-implantitis—red). Diagonally from top left to right, the plots represent univariate distribution of data for the variable in that column. Other plots represent the pairwise scatterplots between the two characteristics. KM, keratinized mucosa; KM–PD, relationship between KM and PD; mPI, modified plaque index; MR, marginal recession; PD, probing depth.

though the presence of plaque was identified in healthy, peri-implant mucositis, and peri-implantitis-diagnosed implants, only high scores were significantly associated with peri-implant diseases. Previously, other studies failed to associate plaque with peri-implantitis;[9,17] this variance could be explained by their dichotomous evaluation, where plaque scores 1–3 were all considered as "present."

MR around dental implants was also significantly associated with peri-implantitis. In further agreement, MR was associated with progressive bone loss,[17] and other cross-sectional studies also showed higher frequencies of peri-implantitis at sites with mucosal dehiscence (>1 mm).[9,15] Soft tissue dehiscence at implant sites could be in fact be a major clinical aspect to consider. High MR values can increase the implant thread exposure and consequently plaque accumulation. Clinicians should contemplate the possibility to perform soft tissue grafts at areas with increased MR scores in order to avoid inflammation and biofilm accumulation at implant sites.

The association between KM and peri-implant diseases has been questioned in previous literature.[18,39] Our

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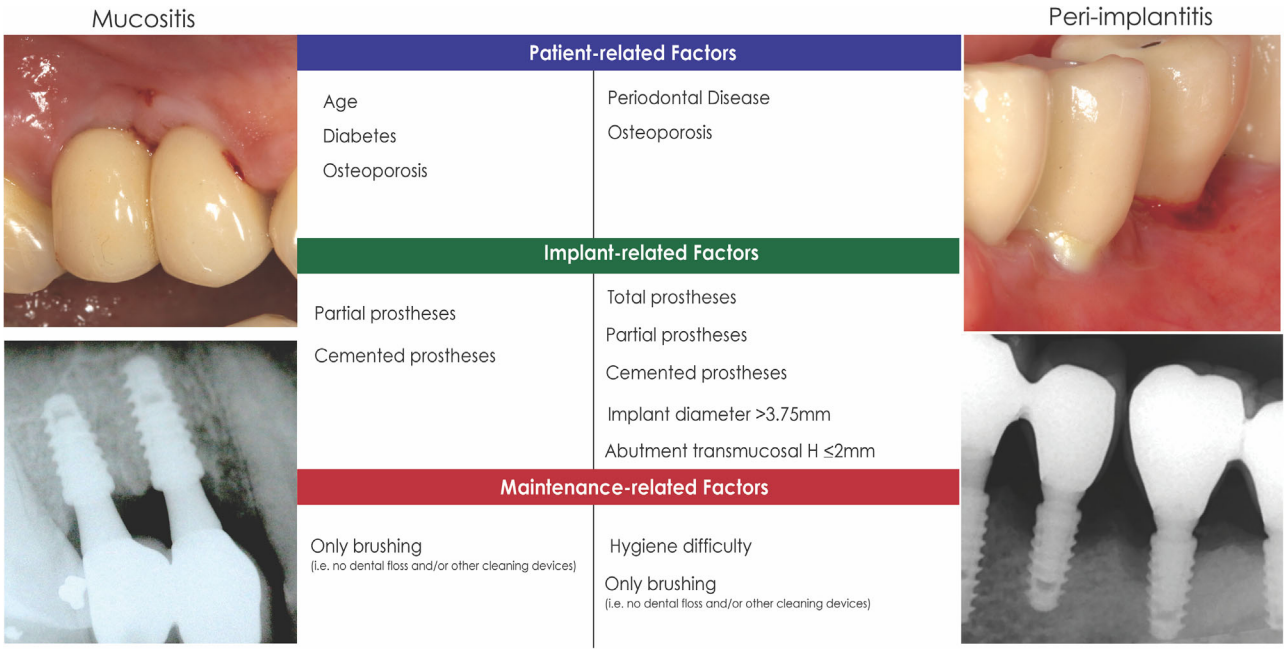

FIGURE 4 Schematic diagram summarizing patient-, implant-, and maintenance-related factors that were statistically significantly associated with peri-implant mucositis and peri-implantitis. H:height.

data associated higher KM values with peri-implantitis. However, it must be noted that KM mean values in all the diagnostic subsets were higher than 3 mm and had very low numerical differences between them. Moreover, the scatterplot did not expose marked trends of KM crossed with other clinical parameters. A possible limitation of the present study could be that KM width scores were not evaluated at the lingual aspects; therefore, the absence of KM at the aforementioned sites could be a factor that alters the results, thus being a limitation in the presented outcomes. Nonetheless, the relationship between KM and PD scores might represent a more important clinical implication toward peri-implant disease progression. KM–PD aims to represent the "protective" mucosa adhered around the implant transmucosal circumference.[40,41] Therefore, negative values correspond to a numerical expression that evidence PD or KM unbalance. Our findings revealed a statistically significant association between lower KM–PD values and peri-implantitis prevalence. Probably, if the peri-implant-adhered mucosa is reduced, the chances of pathogenic factors to invade peri-implant tissues can be higher since the mucosal protective function will be diminished.[42]

To the authors' best knowledge, this is the first study that analyzes the bivariate relationship between two clinical characteristics and its trends to specific peri-implant diagnoses in a scatterplot matrix. This analysis exposed that parameters such as plaque index and MR had a stronger influence on the other clinical characteristics and consequently on peri-implant diagnoses. Biofilm accumulation at implant surfaces is known as a causal factor for peri-implant tissue inflammation and disease progression;[1] however, MR at implant sites might also contribute to peri-implantitis prevalence according to the presented results. A possible explanation could be that soft tissue deficiencies around dental implants can increase the chance for plaque accumulation since the exposed rough implant body can harvest bacterial colonization, inducing inflammation at peri-implant soft tissues.[22,43] It is still an area of future research whether peri-implant phenotype modification could counteract the progression of the disease.[1,44]

Among the limitations of the present study, the risk indicator analyses should be interpreted carefully since the highest OR and the wide CI are results of the high number of variables included for the analyses and the limited sample size, which was calculated using 80% of confidence level. Also, patient-related factors have been analyzed taking the implant as unit where interdependence of the implant within the same patient was not included. Furthermore, the nature of the present observational study does not permit to conclude a cause–effect relationship of the risk factors.[45] In respect to clinical characteristics, our results come from a pool of patients where no exclusion criteria related to periodontitis, smoking habits, or diabetes were applied, which could have modified the clinical parameters. Finally, the scatterplot has a subjective character because a stratified sample is required to statistically demonstrate tendencies. However, the overview of clinical characteristics and their pairwise interactions may boost and encourage further investigations.

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5 | CONCLUSION

In the medium term, the prevalence of peri-implant mucositis and peri-implantitis significantly correlated with systemic diseases of the patients such as osteoporosis, diabetes mellitus, and periodontitis. Prosthetic/implant features correlated to peri-implant diseases were cemented-retained and multiple prostheses, greater implant diameter, lower abutment transmucosal height, and hygiene difficulty factors. Moreover, peri-implant clinical characteristics such as plaque index and mucosal recession scores were significantly associated with both peri-implant diseases.

AUTHOR CONTRIBUTIONS

K.A.B., M.A.B., and C.A.M.B. contributed to the conception and design of the study. K.A.B., B.B.C., and M.A.B. were involved in data collection. K.A.B., B.B.C., and M.E.G.V. analyzed the data. K.A.B. and M.E.G.V., and F.S. performed the data interpretation and drafted the manuscript. C.A.M.B, M.A.B., and F.S. critically revised the manuscript. All authors revised the manuscript and approved the final version.

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CONFLICT OF INTEREST STATEMENT

The authors report no conflicts of interest related to this study.

ORCID

Maria Elisa Galarraga-Vinueza https://orcid.org/0000-0002-4060-0444

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