Received: 14 May 2018 | Revised: 13 August 2018 | Accepted: 30 September 2018

DOI: 10.1111/jcpe.13017

EPIDEMIOLOGY (COHORT STUDY OR CASE–CONTROL STUDY)

WILEY Journal of Clinical Periodontology

Prevalence and risk indicators of peri-implant diseases in Spain

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Funding information
This work was funded by the SEPA (Spanish Society of Periodontology and Osseointegration) Foundation.

Abstract

Aim: To evaluate the prevalence of peri-implant diseases in Spain, as well as the associated risk indicators.

Material and Methods: This is a cross-sectional study using a network of sentinel dentists, who randomly selected 10 patients with implants (placed, at least, 5 years before), which were clinically and radiographically evaluated. Case definitions were established for peri-implant mucositis [bleeding on probing (BOP) and no bone level ≥2 mm] and peri-implantitis (BOP plus bone level ≥2 mm). Potential predictor variables, at univariate and multivariate levels, were explored by means of binary logistic regression.

Results: A total of 49 sentinel dentists provided complete data from 474 implants in 275 patients. At implant level, prevalences for peri-implant mucositis and peri-implantitis were 27% (95% confidence interval [CI] 22–32) and 20% (95% CI: 15–24), respectively, with 17% of implants (14–21) with bone level ≥2 mm without BOP. At patient level, prevalences were 27% (22–32), 24% (19–29) and 18% (13–22), respectively. In the multiple regression analysis, statistically significant associations for peri-implantitis ($p < 0.10$) were found for gender, peri-implant supportive therapy, implant location, diameter and surface, type of prosthesis and access to interproximal hygiene.

Conclusions: In this representative subject sample across Spain, the prevalence of peri-implant diseases was high (51%).

KEYWORDS

peri-implant diseases, peri-implant mucositis, peri-implantitis, Spain

1 | INTRODUCTION

Replacement of teeth with dental implants is a very frequent procedure, and it is associated with high rates of implant survival. However, the incidence of technical and biological complications seems to be frequent (Albrektsson & Donos, 2012; Pjetursson, Karoussis, Burgin, Bragger, & Lang, 2005). These complications may have substantial economic implications (Fardal & Grytten, 2013; Listl, Fischer, & Giannakopoulos, 2014) and effects in the patient's perception of the treatment (Derks, Hakansson, Wennstrom, Klinge, & Berglundh, 2015; Vogel, Smith-Palmer, & Valentine, 2013). Since the number of subjects receiving dental

implants is growing continuously, prevention and treatment of the associated complications represent a serious and relevant challenge.

Among biological complications, peri-implant diseases are considered the most relevant: peri-implant mucositis has been defined as the presence of biofilm-induced inflammation in the peri-implant tissues with no progressive peri-implant bone loss; conversely, peri-implantitis is characterized by progressive peri-implant bone loss, together with inflammation in the peri-implant tissues (Berglundh & Armitage, 2018; Lang & Berglundh, 2011; Lindhe & Meyle, 2008). Since peri-implant diseases share some features with periodontal diseases, initially knowledge on management of the latter was easily transferred to the former. However, it is now evident that peri-implant diseases, and peri-implantitis in particular, usually progresses faster than periodontal diseases and may arise within the first year post-loading (Derks et al., 2016).

In order to better understand peri-implant diseases and to effectively and efficiently implement preventive strategies, it is mandatory to understand their epidemiology in different geographical areas. Therefore, it has been suggested that epidemiological studies with a cross-sectional design, adequate sample sizes and clinical and radiographic records are necessary to study the prevalence and risk indicators of peri-implant diseases (Zitzmann & Berglundh, 2008). Recently, a systematic review, that aimed to evaluate the epidemiology of peri-implant diseases, has been conducted (Derks & Tomasi, 2015): 47 studies were included and the meta-analysis at the patient level reported an estimated prevalence of 19.8% [95% confidence interval (CI): 15.38, 24.27%] for peri-implantitis and 46.83% (95% CI: 38.30, 55.36%) for peri-implant mucositis. The reported variability may depend on different factors, including the length of follow-up or the definition of disease (including the threshold of bone level used for the case definition). The case definition is quite controversial and many different definitions have been proposed/used (Tomasi & Derks, 2012), such as the one coming from the new classification of periodontal and peri-implant diseases, in which in the absence of previous examination, the diagnosis of peri-implantitis can be based on the combination of the presence of bleeding and/or suppuration, probing depths ≥6 mm and bone level ≥3 mm (Berglundh & Armitage, 2018). Other relevant factor is the use of convenience rather than randomized samples, eventually resulting in a potential selection bias (Kleinbaum, Morgenstern, & Kupper, 1981; Patten, 2000).

Although some information on the prevalence of peri-implant diseases is available from studies performed in Spain (Aguirre-Zorzano, Estefania-Fresco, Telletxea, & Bravo, 2015; Canullo et al., 2016; Lopez-Piriz et al., 2012; Mir-Mari, Mir-Orfila, Figueiredo, Valmaseda-Castellon, & Gay-Escoda, 2012; Sanchez-Siles, Munoz-Camara, Salazar-Sanchez, Ballester-Ferrandis, & Camacho-Alonso, 2015; Vazquez Alvarez, Perez Sayans, Gayoso Diz, & Garcia Garcia, 2015), a large epidemiological study was missing. Therefore, the objective of this cross-sectional study was to estimate the prevalence of peri-implant diseases, as well as the associated risk indicators, in dental implants placed in patients treated by a representative sample of sentinel dentists in Spain.

Clinical Relevance

Scientific rationale for the study: In order to better understand peri-implant diseases and to effectively and efficiently implement preventive strategies, it is mandatory to understand their epidemiology in different geographical areas.
Principal findings: The prevalence of peri-implant diseases was high (51%), and relevant factors were associated with peri-implantitis, including gender, peri-implant supportive therapy, implant location, diameter and surface, type of prosthesis and access to interproximal hygiene.
Practical implications: Control of the associated risk indicators may be crucial in the prevention of peri-implant diseases, with special emphasis in supportive therapy and access to hygiene.

2 | MATERIAL AND METHODS

2.1 | Study design

The study was designed as a cross-sectional survey using a network of sentinel dentist. The design and supervision were carried out by a group of experts (Expert Group for Peri-Implant Diseases, Spanish Society of Periodontology and Osseointegration, SEPA). Ethical approval was obtained from the "Comité Central de Ética y Deodontología" of the Spanish Dental Council.

2.2 | Selection of sentinel dentist and patients

In order to identify proper sentinel dentists, and due to the lack of regulation of official specialties in Dentistry in Spain, dentists, in private settings, were invited to participate according to their clinical practice's preference and/or training [periodontists (specialist members of SEPA), oral surgeons/maxillofacial surgeons and general practitioners (GPs)] and geographical areas (Central, North-East, East, North, North-West and South) (Carasol et al., 2016). The inclusion criteria for sentinel dentists were (a) having, at least, 7 years of experience in implant placement, (b) at least 500 implants already placed; (c) being either considered a periodontist, an oral surgeon or a GP and (d) have their practice in a specific geographic area. The included dentists were asked to identify 10 patients, with a predefined sequence table, customized for each dentist according to the year of first implant placement, allowing for the identification of patients which had received implant therapy, at least, 5 years before, as the only inclusion criteria. No exclusion criteria were defined.

2.3 | Sample size calculation

A prior sample calculation was done based on an estimated prevalence of peri-implant diseases, on a Spanish population in a private

setting, of 55.1% at patient level (16.3% peri-implant mucositis and 38.8% peri-implantitis) (Mir-Mari et al., 2012), and considered a 6% absolute precision of confidence interval and a confidence level of 95%. This resulted in an estimated sample size of 264 patients.

2.4 | Calibration of sentinel dentists

Calibration was done through online training. This online training was validated in two workshop sessions including nine dentists each and one trained examiner [gold standard (ISS)]. Kappa values ranged from 0.50 (for keratinized tissue) to 0.81 (probing depth in mesial aspect), suggesting moderate to almost perfect agreement (Landis & Koch, 1977).

2.5 | Data collection

Each sentinel dentist collected data from July 2015 until July 2016 at his/her own clinical setting. Consecutive patients fulfilling the inclusion criteria were then invited to participate in the study. Each dentist included the data in a specifically designed online platform grouped into four categories:

- Sentinel dentist: type of practice, age, years of experience in implant dentistry and number of implants placed in the previous 3 years.
- Patient: sex, age, tobacco, referred medical/systemic conditions, peri-implant check-ups, peri-implant therapy provided (surgical therapy, non-surgical, nothing), periodontal status (untreated or treated periodontitis, no periodontitis), previous periodontal treatment (non-surgical, surgical, supragingival) and supportive periodontal therapy (SPT: no regular, regular).
- Implant: location, brand, length, diameter and surface (machined, rough or combined) were registered, along with the need for regeneration during surgery (guided osseous regeneration previous or simultaneous to implant placement; sinus lift) and the type of prosthesis [single, partial or complete (fixed or removable)].
- Peri-implant health, based on clinical and radiographic examination.

Clinical evaluation was performed with a standardized periodontal probe (SEPA probe, with marks at 3.5 and 5.5 mm) and included the presence of clinical signs of inflammation, plaque (four sites/implant), probing depths (mm) (four sites/implant), bleeding on probing (BOP, four sites/implant), suppuration, presence of keratinized tissue >1 mm and adequate/possible accessibility to interproximal hygiene. After clinical evaluation, included implants underwent a radiographic examination done with the radiograph holders (Rinn System; Dentsply, Konstanz, Germany) provided by the study organization, and were sent to SEPA for determining bone levels. Radiographs were considered adequate if the peaks of the threads were perfectly defined and/or if the whole implant was included in the X-ray.

2.6 | Radiological bone level measurements

Bone level was defined as the distance from the implant shoulder to the first clearly visible contact between the implant surface and the most apical extension of bone. For transmucosal implants, the length of the transmucosal component was subtracted. The known distances of the implants (length and diameter) were used to adjust for distortion and thus calibrate the radiograph (Flores-Guillen, Álvarez-Novoa, Barbieri, Martín, & Sanz, 2018). All measurements were performed by two trained and experienced periodontists using the image software package (AutoCAD 2010™; AutoDesk Inc., San Rafael, CA, USA). The degree of agreement was evaluated with 48 radiographs of the study assessed twice within one week and the accepted error threshold was defined at 0.5 mm. The intra-examiner agreement obtained a kappa value of 0.67 (91.7% concordance; mean difference ± standard deviation 0.22 ± 0.22 mm) for observer 1, and a kappa value of 0.81 (95.8%; 0.15 ± 0.22 mm) for observer 2. The second measurement of both observers was used to calculate inter-examiner agreement (kappa = 0.62). For the inter-examiner agreement, the kappa value was 0.60 (85.7%; 0.23 ± 0.29 mm).

2.7 | Study outcomes

The following case definitions were considered for the analyses of the primary study outcome (prevalence of peri-implant diseases):

- Health: Implants were considered healthy when they have absence of BOP and radiographic bone levels <2 or <3 mm.
- Peri-implant mucositis was considered when the implant has BOP and radiographic bone levels <2 or <3 mm.
- Peri-implantitis was considered when the implant has BOP and radiographic bone levels ≥2 (Sanz & Chapple, 2012) or ≥3 mm (Berglundh & Armitage, 2018).
- Whenever an implant has radiographic bone levels ≥2 or ≥3 mm in the absence of BOP, it was considered in a different entity and was excluded from the three previous groups.

All other study outcomes were considered secondary outcomes (information coming from questionnaires, clinical and radiographic outcomes).

2.8 | Statistical analyses

The descriptive analysis was conducted using SPSS Windows 20.0 (IBM Corp. released 2011, Armonk, NY, USA). Significance analysis and 95% confidence interval (CI) calculation were obtained with SPSS Windows 20.0, if the unit of analysis was the patient, and with SUDAAN 7.0 (RTI International, Research Triangle Park, NC, USA) when the implant was the unit of analysis, to account for clustering (i.e., multiple implants within the patient). Potential predictor variables, at univariate and multivariate levels, were explored, by means of binary logistic regression, for peri-implant mucositis (in comparison to healthy) and for peri-implantitis (in comparison to healthy,

mucositis and bone level ≥2 or ≥3 mm with no BOP). The potential predictor variables assessed included all those variables measured at a patient and/or implant level (see Table 1). Detailed statistical methods are reported associated with each specific table.

3 | RESULTS

One hundred and fifty dentists were invited to participate and 64 finally accepted and assessed a total of 369 patients and 689 implants. Out of the 689 included implants, 658 were still in place. Among these implants, an acceptable radiographic assessment was not available for 184 implants; therefore, 474 implants in 275 patients were included in the present analysis, evaluated by 49 sentinel dentists (20 periodontists, 12 oral surgeons and 17 GP). All the dentists who were invited to participate, both those finally included and those who declined the offer, met the two criteria required: at least 7 years of experience in implant dentistry and at least 500 implants placed; in addition, no significant differences in age, sex or distribution by geographical area were observed, so it can be assumed that both groups are homogeneous.

3.1 | Sample description

In Table 1, a description of the included patients and implants is presented, together with the clinical and radiographic examination of the selected implants. Forty-five per cent of the patients were males, and the mean age was 60, with the fifth (29%) and sixth (35%) decades of life being the most represented. Most patients were non-smokers (72%) and systemically healthy (66%). Peri-implant check-ups were scheduled at least once per year for 64% of the patients, and non-surgical therapy has been provided for 82% of them. A similar proportion of patients had treated periodontitis (49%) or no periodontitis (47%), while only 4% had untreated periodontitis. Previous periodontal therapy included non-surgical therapy for 39% of the patients and periodontal surgery for 8%. 55% of the patients were enrolled in a SPT program.

A mean of 1.88 implants were included per patient, being the most frequent option to include just one implant (57%). Upper- (37%) and lower - (40%) posteriors, were the most frequent locations, with implants of at least 10 mm representing 89%, and with a diameter between 3.6 and 4.5 mm in 62% of the implants. Most implants showed a rough surface (95%) and were placed without bone regeneration (85%). The most frequent prosthesis designs were fixed partial bridges (51%) and single restorations (35%). Access to interproximal hygiene was considered adequate in 95% of the cases.

Implants were in place for 9.0 years [standard deviation (*SD*) = 1.7 years; range: 5–13 years]; 46% presented BOP, 19% visual signs of inflammation, 44% plaque and 7% suppuration. Mean radiographic bone level was 1.84 (*SD* 1.79) mm (range 0.00–13.17 mm) and mean probing depth 2.76 (*SD* 1.33) mm (range 1.75–7.00).

3.2 | Prevalence of peri-implant conditions (Table 2)

According to the case definition with a cut-off of 2 mm of bone level, at implant level, the prevalences were: 36% (95% CI: 31–41) for peri-implant health, 27% (95% CI: 22–32) for mucositis, 20% (95% CI: 15–24) for peri-implantitis and 17% (95% CI: 14–21) for bone levels ≥2 mm without BOP. At patient level, the prevalences were: 31% (95% CI: 25–36) for peri-implant health, 27% (95% CI: 22–32) for mucositis, 24% (95% CI: 19–29) for peri-implantitis and 18% (95% CI: 13–22) for bone level ≥3 mm without BOP. The prevalences of the peri-implant conditions with a cut-off of 3 mm of bone levels are depicted in Table 2.

3.3 | Association of peri-implant conditions with clinical findings (Table 3)

The peri-implant condition was significantly associated ($p < 0.01$) with visual signs of inflammation, presence of plaque, mean probing depth and presence of suppuration. No association was found with the presence of keratinized tissue >1 mm in mid buccal.

3.4 | Association of peri-implantitis with patient-based and implant-based risk indicators

The risk analysis for mucositis showed that none of the studied variables, included in Table 1, was significantly associated at univariate or multivariate level with mucositis (against healthy) (results not shown).

The risk analysis for peri-implantitis is presented in Table 4, depicting the references for each particular analysis [odd ratios (OR) = 1.0], the 95% CI and the *p* values, for the multivariate analyses.

In the univariate analysis (data not shown), factors statistically associated with peri-implantitis (*p* value ≤0.05) were found for: peri-implant therapy provided (higher risk for surgical therapy, protective for non-surgical therapy), periodontal status (higher risk for treated periodontitis, but even higher for untreated periodontitis), SPT (higher risk for no regular SPT), implant location (higher risk forlower-anteriors) implant diameter (the narrower, the higher the risk), type of prosthesis (higher for complete rehabilitations, especially for hybrid design), and access to interproximal hygiene (higher for no access).

In the multiple regression analysis, eight variables entered the final model (see Table 4). Among them, six tested significantly ($p \leq 0.05$): sex (male gender being protective), SPT (higher risk for no regular SPT), implant location (higher risk for lower-anteriors), implant diameter (higher risk for diameters ≤3.5 mm), implant surface (higher risk for smooth surfaces), type of prosthesis (higher for complete rehabilitations, especially for metal-ceramic design), and access to interproximal hygiene (higher for no access). The highest strength of the association was observed for complete rehabilitations, especially for metal-ceramic design (OR = 5.9;

TABLE 1 Description of studied patients (*n* = 275) and implants (*n* = 474)

Variable (categories)	Mean ± *SD* or % distribution[a]
Patient-based variables (*n* = 275 patients)	
N implants, mean ± *SD*	1.88 ± 1.58
# implants/patient, % (1—2 to 4—5 to 11)	57—38—5
Sex, % (Male—Female)	45—55
Age (years), mean ± *SD*	60 ± 11
Age (years) % (31 to 50—51 to 60—61 to 70—71 to 87)	18—29—35—17
Smoking, % (≥10 cig/day—<10 cig/day—Former smoker—No)	14—6—8—72
# Medical/systemic conditions, % (≥2—1—Healthy)	5—29—66
# Peri-implant check-ups, % (Erratic—Once a year or more frequently)	36—64
Peri-implant therapy provided, % (surgical therapy—non-surgical—nothing)	5—82—13
Periodontal status, % (untreated—treated—no periodontitis)	4—49—47
Previous periodontal treatment, % (non-surgical—surgical—supragingival)	39—8—53
Supportive periodontal therapy, % (no regular—regular)	45—55
Baseline implant-based variables (*n* = 474 implants)	
Location (lower-anterior—upper-anterior—upper-posterior—lower-posterior)	10—13—37—40
Length in mm, mean ± *SD*[b]	11.3 ± 1.8
Length in mm, % (<10 mm.—≥10 mm.)[b]	11—89
Diameter in mm, mean ± *SD*[b]	4.2 ± 0.5
Diameter in mm, % (0 to 3.5—>3.5 to 4.5—>4.5)[b]	10—62—28
Surface roughness, % (smooth—rough—intermediate)	5—65—30
GBR, % (simultaneous—previous—no regeneration)	11—4—85
Sinus lift, % (Yes—No)	5—95
Prosthesis, % (overdenture—comp. hybrid—comp. metal-ceramic—bridge—single)	5—5—4—51—35
Access to interproximal hygiene, % (No—Yes)	5—95
Follow-up (years)	
mean ± *SD*	9.0 ± 1.7
Distribution % (5 to 7—8—9—10—11 to 13)	20—21—20—18—21
Final Peri-Implant variables	
Bleeding on probing, % (Yes—No)	46—54
RxBL in mm, mean ± *SD*	1.84 ± 1.79
RxBL in mm, % (<1—1 to <2—2 to <3—3 to <4—≥4)	37—26—19—8—10
Peri-implant condition (c.p. 2 mm)[c], % (Healthy—Mucositis—BL[d]—Peri-implantitis)	36—27—17—20
Peri-implant condition (c.p. 3 mm)[c], % (Healthy—Mucositis—BL[d]—Peri-implantitis)	47—35—7—11
Final Clinical Implant Variables (i.e., proxy variables to PIP) (*n* = 474 implants)	
Visual assessment: oedema, redness % (Yes—No)	19—81
Dental plaque, % (Yes—No)	44—56
Probing depth in mm, mean ± *SD*	2.76 ± 1.33
Probing depth in mm, % (≥6—<6-4—<4)	14—39—47
Suppuration on probing, % (Yes—No)	7—93
Keratinized tissue-midbuccal >1 mm, % (Yes—No)	80—20

Notes. *SD*: standard deviation; cig.: cigarette; GBR: guided bone regeneration; RxBL: radiographic bone level; BL: bone level, according to c.p.; comp.: complete; c.p., cut-off point; PIP: peri-implantitis.
[a]Per cent distribution without decimals across categories. [b]Missing in 52 implants. [c]A detailed description of this variable is provided in consecutive tables. [d]Radiographic bone level, without bleeding on probing.

95% CI: 2.3–15.4; $p < 0.01$), followed by implants located in the lower-anterior sextant (OR = 5.6; 95% CI: 2.1–15.3; $p < 0.01$) and no access to interproximal hygiene (OR = 4.2; 95% CI: 1.0–18.1; $p < 0.05$).

4 | DISCUSSION

The results of the present cross-sectional study on the prevalence of peri-implant diseases in Spain have shown that 24% (95% CI: 19–29)

TABLE 2 Prevalence of different peri-implant conditions

	At patient level (*n* = 275)		At implant level (*n* = 474)		
Status[a]	*n*	% (95% CI)	*n*	% (95% CI[b])	RxBL (mm) (provide space) Mean ± *SD* [min-max]
With criterion #1 (RxBL cut-off point 2 mm)					
Healthy (no bleeding, RxBL < 2 mm)	85	31 (25–36)	171	36 (31–41)	0.84 ± 0.62 [0.00–1.98]
Mucositis (bleeding, RxBL < 2 mm)	75	27 (22–32)	127	27 (22–32)	0.81 ± 0.65 [0.00–1.92]
BL without bleeding (no bleeding, RxBL ≥ 2 mm)	49	18 (13–22)	83	17 (14–21)	3.26 ± 1.66 [2.00–13.17]
Peri-implantitis (bleeding, RxBL ≥ 2 mm)	66	24 (19–29)	93	20 (15–24)	3.79 ± 1.91 [2.00–11.57]
BL with or without bleeding	115	42 (36–48)	176	37 (31–43)	3.54 ± 1.81 [2.00–13.17]
With criterion #2 (RxBL cut-off point 3 mm)					
Healthy (no bleeding, RxBL < 3 mm)	115	42 (36–48)	222	47 (41–53)	1.20 ± 0.86 [0.00–2.96]
Mucositis (bleeding, RxBL < 3 mm)	101	37 (31–42)	166	35 (30–40)	1.19 ± 0.90 [0.00–2.95]
BL without bleeding (no bleeding, RxBL ≥ 3 mm)	20	7 (4–11)	32	7 (4–9)	4.64 ± 1.98 [3.01–13.17]
Peri-implantitis (bleeding, RxBL ≥ 3 mm)	39	14 (10–18)	54	11 (8–15)	4.79 ± 1.97 [3.00–11.57]
BL with or without bleeding	59	21 (17–26)	86	18 (14–23)	4.74 ± 1.96 [3.00–13.17]

Notes. CI: confidence interval; SD: standard deviation; min: minimum; max: maximum; RxBL: radiographic bone level; BL: bone level, according to cut-off point.
[a]For patient level, it is defined according to the worse implant status within the patient. [b]95% CI, calculated with procedure DESCRIPT of SUDAAN.

of the subjects suffered from peri-implantitis (bone level ≥2 mm) and 27% (95% CI: 22–32) from peri-implant mucositis. The corresponding figures at the implant level were 20% and 27%, respectively. In addition, different associated indicators were identified including gender, previous supportive and therapeutic care, implant characteristics, type of prosthesis and access to interproximal hygiene.

The reported prevalence for peri-implantitis is slightly higher than those previously reported in Spain (10.3%–16.3%) (Aguirre-Zorzano et al., 2015; Canullo et al., 2016; Mir-Mari et al., 2012), but similar to those coming from other populations (3.3%, Frisch, Ziebolz, Vach, & Ratka-Kruger, 2015, to 63.7% at the patient level, Renvert, Aghazadeh, Hallstrom, & Persson, 2014). Reasons for the observed variability may be multiple: use of convenience samples, case definitions or limitations of bleeding or bone level as outcome variables. Convenience samples lead to a high risk of selection bias, and to overcome that problem, randomized and representative samples, with adequate size, of the entire population should be included (Fowkes & Fulton, 1991). In the present study, 49 sentinel dentists, with different professional profiles, participated in data collection, and patients were randomly selected. With regard to the case definition of peri-implantitis, prevalences can range from 1% to 47% depending on the use of nine different definitions (Derks & Tomasi, 2015). Efforts have been made in order to promote the use of consensus definition, and a threshold of 2 mm plus BOP was recommended (Sanz & Chapple, 2012), while more recently the threshold for bone loss has been suggested to be 3 mm in the absence of previous radiographs (Berglundh & Armitage, 2018). Another critical issue is the technique used to measure bone levels, since radiographs have relevant limitations (Benic, Sancho-Puchades, Jung, Deyhle, & Hammerle, 2013; Tyndall & Brooks, 2000) and overestimate bone levels (Garcia-Garcia, Mir-Mari, Benic, Figueiredo, & Valmaseda-Castellon, 2016; Schliephake, Wichmann, Donnerstag, & Vogt, 2003), especially when using panoramic radiographs (Lam, Ruprecht, & Yang, 1995; Mengel, Kruse, & Flores-de-Jacoby, 2006).

TABLE 3 Association between peri-implantitis (defined with cut-off point of 2 mm of radiographic bone level) and final clinical implant variables (i.e., proxy variables to peri-implantitis)[a] (*n* = 474 implants from 275 patients)

Peri-implant status	*n*	Visual oedema (%)	Plaque (%)	Probing depth (mm) Mean ± *SD*	Suppuration (%)
Healthy	171	8	31	2.20 ± 0.74	1
Mucositis	127	17	52	2.72 ± 1.22	5
BL without BOP	83	17	35	2.68 ± 1.28	4
Peri-implantitis	93	44	65	3.89 ± 1.67	25
p-Value[b]		<0.01	<0.01	<0.01	<0.01

Notes. SD: standard deviation; BOP: bleeding on probing; BL: bone level, according to cut-off point. (≥2 mm)
[a]The variable *Keratinized tissue-midbuccal >1 mm* was excluded since it was not significantly associated with peri-implantitis. [b]With CROSSTAB (percentages) and REGRESS (means) procedures in SUDAAN 7.0.

TABLE 4 Multivariate binary logistic regression model[a], with peri-implantitis (defined with cut-off point of 2 mm of radiographic bone level) as dependent variable in 474 implants (from 275 patients)

Variable	*n*	% Peri-Implantitis	OR (95% CI)[b]
Sex			$p = 0.05$
Male	224	15	0.5 (0.3–1.0)
Female	250	24	1.0
Medical/systemic conditions			$p = 0.07$
2 or more systemic conditions	30	3	0.2 (0.1–1.8)
1 systemic condition	112	26	1.7 (0.9–3.4)
Systemically healthy	332	19	1.0
Supportive periodontal therapy			$p = 0.02$
No regular	198	25	2.3 (1.2–4.4)
Regular	276	16	1.0
Implant location			$p = 0.02$
Lower-anterior	48	42	4.9 (1.8–13.6)
Upper-anterior	61	25	1.3 (0.5–3.2)
Upper-posterior	174	19	1.3 (0.7–2.8)
Lower-posterior	191	13	1.0
Implant diameter in mm			$p = 0.02$
Unknown	52	13	1.3 (0.5–3.7)
0–3.5	41	39	4.0 (1.2–14.2)
>3.5–4.5	262	22	2.7 (1.3–5.6)
>4.5	119	10	1.0
Implant surface roughness			$p = 0.08$
Smooth	22	46	3.0 (1.0–8.7)
Rough	309	18	0.9 (0.5–1.6)
Intermediate	143	18	1.0
Prothesis			$p < 0.01$
Complete, removable (overdenture)	24	21	0.9 (0.2–3.6)
Complete, fixed (hybrid)	25	44	2.2 (0.3–14.5)
Complete, fixed (metal-ceramic)	21	33	8.1 (2.6–25.3)
Partial, fixed ("bridge")	239	22	2.0 (1.0–4.0)
Single restoration	165	10	1.0
Access to interproximal hygiene			$p = 0.02$
No	23	61	4.9 (1.2–19.6)
Yes	451	17	1.0

[a]With LOGISTIC procedure in SUDAAN 7.0. Potential predictor variables were all variables of Table 1, except "Peri-implant therapy provided", since it is clearly related to output. Starting with a model with all variables with $p \leq 0.10$ at univariate level (Sex, Medical/systemic conditions, #Peri-implant check-ups, Periodontal status, Supportive periodontal therapy, Implant location, Implant diameter, Implant surface roughness, Prothesis and Access to interproximal hygiene) (detailed results not shown), a backward stepwise method was used, maintaining those variables with a corrected $p \leq 0.10$. [b]Odds ratio (OR) and 95% confidence interval (CI).

Thus, in the present study, only parallelized periapical radiographs, with predefined quality levels, were used.

The prevalence of peri-implant mucositis in the present investigation (27%) was slightly inferior to those obtained in other cross-sectional studies and systematic reviews (Derks & Tomasi, 2015; Konstantinidis, Kotsakis, Gerdes, & Walter, 2015; Passoni et al., 2014; Rokn et al., 2017). This might be due to the design of the present study, with 49 sentinel dentists, that makes almost impossible to standardize the probing force of the different participants. This accentuates the risk of false negative bleeding records and, therefore, may impact the peri-implant diagnosis (Merli et al., 2014). Furthermore, in the present study, a group with bone levels ≥2 mm, but not BOP, was also identified, comprising 24% of the patients and 20% of implants. Qualifying this group has been a challenge in previous studies: for example, according to Mir-Mari et al. (2012), 18.2% of the patients were allocated to that group and

were defined as "clinically stable". In the present study, this group was considered a separate entity since: (a) they could show treated and/or inactive peri-implantitis (Fransson et al., 2010; Schwarz, Sculean, Engebretson, Becker, & Sager, 2015); (b) some of these implants could represent false negatives for BOP (Merli et al., 2014); (c) they could respond to iatrogenic situations during implant placement (Barone et al., 2016; Esposito, Ekestubbe, & Grondahl, 1993; Merheb, Quirynen, & Teughels, 2014) that favours future pathology (Jung et al., 2017; Schwarz, Sahm, & Becker, 2012), but it cannot be excluded that they may represent a group with false negative values for BOP.

Although cross-sectional study designs do not allow establishing cause-effect relationships, the possible association between different risk indicators and peri-implantitis was assessed. All clinical variables were associated with the peri-implant condition, except the presence of keratinized mucosa. Although some publications have linked its absence with an increased risk of inflammation (Pranskunas, Poskevicius, Juodzbalys, Kubilius, & Jimbo, 2016; Roccuzzo, Grasso, & Dalmasso, 2016; Roos-Jansaker, Renvert, Lindahl, & Renvert, 2006), its association with peri-implantitis is still unclear (Ladwein, Schmelzeisen, Nelson, Fluegge, & Fretwurst, 2015; Wennstrom & Derks, 2012).

Results obtained after multiple multilevel regression analysis have shown that the probability of suffering from peri-implantitis was approximately 4–5 times higher in implants placed in the lower-anterior area, with complete fixed prosthesis and with lack of access to interproximal hygiene. This is in line with previous investigations (Dalago, Schuldt Filho, Rodrigues, Renvert, & Bianchini, 2017; Serino & Strom, 2009), although the small number of implants/patients in the "exposed" groups in the present study suggests that the results should be interpreted with caution. The impact of the oral region where the implant is placed on the risk of disease remains unclear (Derks et al., 2016; Jemt, 2017).

Previous history of periodontitis (Derks et al., 2016; Karoussis, Kotsovilis, & Fourmousis, 2007; Roccuzzo, Bonino, Dalmasso, & Aglietta, 2014; Roos-Jansaker et al., 2006) and tobacco consumption (Carcuac & Jansson, 2010; Esposito, Hirsch, Lekholm, & Thomsen, 1998; Roos-Jansaker et al., 2006) have been associated with an increased risk of peri-implantitis; however, the present multilevel analysis failed to find these associations. For tobacco, the present results are in agreement with other epidemiological investigations (Dalago et al., 2017; Jepsen et al., 2015; Konstantinidis et al., 2015; Marrone, Lasserre, Bercy, & Brecx, 2013; Renvert et al., 2014). The lack of a positive association could be due to the different cut-off criteria to define a patient as a smoker, the time of consumption or the percentage of former smokers included in the category of non-smokers. Regarding history of periodontitis, periodontal diagnosis was performed according to the individual clinical criteria of each of the sentinel dentists, without proper standardization. Nevertheless, a strong association between peri-implantitis and the frequency of SPT was identified, as well as the specific maintenance approach around dental implants. This is in agreement with other studies and highlights the importance of adapting maintenance protocols in patients undergoing implant therapy (Costa et al., 2012; Heitz-Mayfield, Needleman, Salvi, & Pjetursson, 2014; Monje et al., 2016; Roccuzzo et al., 2014).

The effect of the implant surface characteristics on the prevalence of peri-implantitis is widely debated in the literature (De Bruyn et al., 2017; Esposito, Coulthard, Thomsen, & Worthington, 2005; Renvert, Polyzois, & Claffey, 2011). Worse results were found for smooth surfaces as compared to rough (OR = 3.7; 95% CI: 1.2–8.7), but with only 22 implants with smooth surface. The higher frequency of peri-implantitis in narrow implants could be related with the location where those implants are placed, with less bone availability and bone thicknesses, increasing the risk of crestal bone loss (Spray, Black, Morris, & Ochi, 2000; Strietzel, Nowak, Kuchler, & Friedmann, 2002).

The limitations of the present study should be acknowledged. The lack of a retrospective standardized baseline (prosthetic delivery day) radiological examination did not allow assessing for accurate bone level measurements. Furthermore, a larger sample size could have contributed to have a greater statistical power for the multivariate analysis and, therefore, to obtain more robust conclusions. In addition, the use of a network of sentinel dentists, although providing a good external validity, leads to high heterogeneity for the different criteria used. Some possibly relevant factors could not be properly assessed, including the comparison of experienced versus less experienced operators (since an inclusion criterion was having placed at least 500 implants, aiming at selecting a more representative group of sentinel dentist), the specialization of the dentist (since the numbers of each specific clinical practice′s preference and/or training did not allow for a proper evaluation), or the type of retention (cemented or screw-retained). However, with the available variables to verify that the sample is representative of the Spanish dentists (distribution of the professionals by geographical area, age, sex and years of professional experience), it can be confirmed that the sample used is distributed homogeneously with respect to the Spanish dentists.

In conclusion, the prevalence of peri-implant diseases in Spain was 27% for peri-implant mucositis and 24% for peri-implantitis, at subject-level. Associated indicators included gender, previous supportive and therapeutic care, implant characteristics, type of prosthesis and access to interproximal hygiene, with the strongest association for implants placed in the lower- anterior area, complete fixed prosthesis and with lack of access to interproximal hygiene.

ACKNOWLEDGEMENTS

The authors would like to acknowledge Juan Flores and Cristina Carral for their work measuring the radiographs, and Jan Derks, for his suggestions in the design of the study. In addition, the scientific societies *Sociedad Española de Cirugía Bucal* (SECIB) and *Sociedad Española de Cirugía Oral y Maxilofacial* (SECOM), together with *Consejo General de Dentistas* have been very helpful in the selection of the sentinel dentists, and their support is sincerely acknowledged. Special thanks to the network of Sentinel dentists, listed in alphabetic order: Laurence Adriaens (Baleares), Beatriz

Álvarez Bruda (Valencia), Luis Aracil Kessler (Madrid), Jesús Arbonies Leranoz (Navarra), Nicolás Belmonte Jove (Albacete), Cristian Bouchard Ridruejo (Badajoz), Pedro José Buitrago Vera (Valencia), Gustavo Cabello Domínguez (Málaga), Blanca Cabezas Hernández (Asturias), Vicente Calvarro (Albacete), Jesús Carrero Fernández (Madrid), José Jesús Castro Padial (Málaga), Susana Cuesta Frechoso (Asturias), Conchita Curull Gasol (Tarragona), Jesús García de Blas Rodríguez (Cáceres), Marcos de la Osa Alonso (Madrid), Javier de Miguel Figuero (Madrid), Francisco J. Enrile (Huelva), Mariano Escudero (Barcelona), Sebastián Fabregues (Baleares), Juan Miguel Franganillo García (Madrid), Manuel Fuentes Candelas (Barcelona), Francisco Javier García Jerónimo (Granada), María García Santacruz (Madrid), Fernando García Vélez (Murcia), Maribel González Martín (Sevilla), Adrián Guerrero (Málaga), Agustin Hernández Pajarón (Cuenca), Miguel Ángel Iglesia Puig (Zaragoza), Víctor Iglesias Blázquez (Zaragoza), Berta Legido Arce (Madrid), Mar Longás Jiménez (Zaragoza), Manuel López Nicolás (Murcia), Juan Antonio López Mumpau (Sevilla), Juan López-Quiles Martínez (Madrid), Ángel Lorenzo Sáez (Pontevedra), Jaime Lucas Pérez-Romero (Madrid), Juan Martínez Dalmau (Asturias), Enrique Martínez Merino (León), Jorge Mejía Torres (Madrid), Fernando Menéndez Gallego (Madrid), Pedro Monlleo Lloret (Valencia), Joaquín Montesanto Rota (Málaga), Marta Moreno Aguirre (Madrid), José Nart Molina(Barcelona), José Antonio Pascual Aramburu (Valladolid), Francisco Javier Pedruelo Martin (Valladolid), Manuel Peleato Sánchez (Navarra), Beatriz Pérez Dorao (Cádiz), Mario Pérez-Sayans García (Pontevedra), Tomás Portaceli Armiana (Valencia), Albert Ramírez Rámiz (Barcelona), Mari Carmen Ramos Martínez (Almería), Juan Rumeu Milà (Barcelona), Ángel Salgado García (Pontevedra), Arturo Sánchez Pérez (Murcia), Francisco Sánchez Zafra (Córdoba), Gorka Santamaria Arrieta (Vizcaya), Jorge Serrano Granger (Madrid), Cristina Serrano Sánchez-Rey (Ciudad Real), Sergi Torne Durán (Barcelona), Juan Ramón Velilla Esteibar (Guipúzcoa), Francisco Vijande Díaz de Corcuera (Vizcaya), Ion Zabalegui Andonegui (Vizcaya).

CONFLICT OF INTEREST

The authors declare that they have no conflict of interests.

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How to cite this article: Rodrigo D, Sanz-Sánchez I, Figuero E, et al. Prevalence and risk indicators of peri-implant diseases in Spain. *J Clin Periodontol*. 2018;00:1–11. https://doi.org/10.1111/jcpe.13017