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Prevalence and risk/protective indicators of buccal soft tissue dehiscence around dental implants

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Abstract

Aim: To evaluate the prevalence of buccal peri-implant soft tissue dehiscence (PISTD) in anterior implants and to identify the risk/protective indicators of PISTD in implants not suffering peri-implantitis.

Materials and methods: 240 randomly selected patients from a university clinic database were invited to participate in the present cross-sectional study. Those who accepted, after the evaluation of their medical and dental records, were clinically examined to assess the prevalence of buccal PISTD in non-molar implants. Multilevel multivariate logistic regression analyses were then carried out to identify those factors associated either positively (risk) or negatively (protective) with buccal PISTD in implants without peri-implantitis.

Results: 92 patients with a total of 272 dental implants were analysed. At implant-level, the prevalence of buccal PISTD was 16.9%, while when selecting only implants without peri-implantitis it was 12.0%. Buccal PISTD was present in 26.7% of the implants diagnosed with peri-implantitis. The following factors were identified as risk/protective indicators of buccal PISTD in implants without peri-implantitis: malposition (too buccal vs. correct: OR=14.67), thin peri-implant phenotype (OR=8.31), presence of at least one adjacent tooth (OR=0.08) and presence of abutment (OR=0.12).

Conclusions: PISTD are highly prevalent among patients with dental implants in this university-based population, and several factors were identified as risk and protective indicators of PISTD in implants not suffering peri-implantitis.

KEYWORDS
abutment, aesthetics, biological complications, biotype, cross-sectional studies, dental implants, dental prosthesis, epidemiology, implant failure, malposition, peri-implant recessions, PISTD, risk factors, soft tissue deficiencies, vestibular

1 | INTRODUCTION

Although dental implants present high long-term survival rates (Pjetursson et al., 2012; Derks et al., 2015; Jemt et al., 2015; Chrcanovic et al., 2016), the concept of success in implant dentistry has evolved in the last decades to include additional criteria, being aesthetics one of the most relevant ones for the patients (Papaspyridakos et al., 2012). One of the most important determinants of soft tissue aesthetics is the apico-coronal level of the buccal

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mucosal margin, mainly when this margin is not in harmony with the adjacent teeth (Furhauser et al., 2005). The apical shift of the peri-implant mucosal margin around implant-supported restorations has been termed "peri-implant soft tissue dehiscence" (PISTD) and in light of the previously referred aesthetic implications, its presence may compromise the success of the implant prosthetic rehabilitation (Sculean et al., 2017; Mazzotti et al., 2018).

There is preliminary evidence that PISTD, similarly to localized gingival recessions around teeth, may represent a localized condition characterized by the apical shift of the buccal peri-implant mucosa in healthy or peri-implant mucositis implants. However, this condition can also be present at implants affected by peri-implantitis (Romandini et al., 2021a). Its diagnosis, however, lacks a fixed reference, such as the cemento-enamel junction for gingival recessions. Accordingly, the manifestation of PISTD is also dependent on the characteristics of the implant design and restoration, and can therefore result in a longer crown with respect to the contralateral natural tooth or in the exposure of the implant/abutment polished metal or zirconia surface (Mazzotti et al., 2018). The implant malposition (too buccal) has been suggested as the most important risk indicator for PISTD, while the presence of adjacent natural teeth, keratinized tissue >2 mm, cemented restorations and two-pieces implants have emerged as protective ones (Sanz-Martín et al., 2021).

Even though several reconstructive interventions have been proposed for covering these peri-implant dehiscence defects (Roccuzzo et al., 2013; Zucchelli et al., 2013; Mazzotti et al., 2018; Roccuzzo et al., 2018; Zucchelli et al., 2018, 2019, 2020), the success rates, defined by the percentage of the complete coverage, are often limited even in the most favourable cases (Roccuzzo et al., 2018; Zucchelli et al., 2018). Consequently, a key strategy for the management of buccal PISTD is their prevention based on the control of their risk factors.

However, in spite of their clinical relevance, the knowledge on the prevalence of PISTD and the associated risk and protective factors is very scarce and limited to convenience samples from some specific treatment protocols (i.e. type 1 implant placement), what limits their generalizability. It was, therefore, the aim of the present study to provide estimates on the prevalence and severity of buccal PISTD and to identify the risk/protective indicators of PISTD in implants not suffering peri-implantitis, analysing a university-representative population.

Clinical Relevance

Scientific rationale for study: In spite of their clinical relevance, the knowledge on the prevalence of PISTD and the associated risk/protective indicators is very scarce and limited to convenience samples from some specific treatment protocols, what limits their generalizability.

Principal findings: At implant-level, the prevalence of buccal PISTD in implants without peri-implantitis was 12.0%. Implants positioned too buccally and thin peri-implant phenotype resulted as risk indicators for PISTD in implants without peri-implantitis, while the presence of an abutment and of an adjacent tooth as protective indicators.

Practical implications: If causality is proven, in consideration of the challenging treatment of PISTD the identified risk/protective indicators should be included in preventive strategies.

2 | MATERIALS AND METHODS

This cross-sectional study is being reported following the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) guidelines (Vandenbroucke et al., 2007; Elm et al., 2007). It was conducted in accordance with the Helsinki declaration of human studies, and the research protocol was ethically approved by the CEIC Hospital Clínico San Carlos, Madrid, Spain (19/182-E). All participants have provided their informed consent prior to their inclusion in the study.

2.1 | Sampling procedures

The detailed procedures of sampling are reported elsewhere (Romandini et al., 2021b). In brief, a protocol using a stratified multistage sampling method was employed for all patients who received implants in the Postgraduate Clinic of Periodontology of the Complutense University of Madrid from September 2000 to July 2017. Using computer-generated randomization lists, three patients from every periodontist (or postgraduate student in periodontology) who had placed implants in at least 10 patients were selected. During each academic year, clinicians who placed implants in less than 10 patients were grouped in a single category and 3 patients were also selected for this group.

Those selected patients were invited to participate in the study by telephone calls on the numbers reported in their clinical charts. At least five telephonic attempts on different days were made before discarding the patients from the inclusion list.

2.2 | Data collection

The subjects who accepted to participate underwent a thorough data collection process, including the collection of demographic and medical/dental history data, a clinical and radiographic examination and an analysis of their past dental records (Romandini et al., 2021b).

The subjects' history was first retrieved by a self-reported questionnaire that was filled, after a brief explanation by one interviewer, by the study participants. It was then followed by a structured interview on a series of standardized questions made by a trained interviewer. As part of the self-reported questionnaire, the oral health impact profile 14 was assessed using its validated Spanish version (OHIP-14Sp; León et al., 2014). Moreover, the participant

satisfaction with regard to the aesthetics of their implant rehabilitations was evaluated through a visual analogue scale (100 mm VAS), with the left limit indicating "absolutely not satisfied" and the right one "very satisfied".

The clinical oral examination was carried out by 2 calibrated examiners (CL & IP) and included the assessment of patient-, restoration- and implant-related variables. Patient-related variables included the assessment of periodontal status according to the AAP/CDC case definitions (Eke et al., 2012) and the number of remaining teeth. The implant supported restoration data included the type of restoration and its retention. All the osteointegrated implants still present in the patients' mouth at the time of the examination (including those placed in external clinics) and having at least one year of loading (either proven by dental charts or confirmed by the patients) were evaluated. The implant-related examination also included the assessment of the location of each implant, its correct placement (subjective evaluation: adequate or buccally/lingually mispositioned), presence of adjacent teeth, keratinized tissue height (KTH), mobility of mucosal margin, peri-implant phenotype (De Rouck et al., 2009), tissue thickness at the mucosal margin and presence of a prosthetic design which did not allow appropriate access to oral hygiene. In each implant, the following measurements were also collected with a manual UNC-15 periodontal probe (PCP15; Hu-Friedy, Chicago, IL, USA) at 6 sites/implant: PISTD depth, probing pocket depth (PPD), bleeding and suppuration on probing (BoP/SoP, within 30 s), and presence of visible plaque.

The inter-rater agreement for the key implant-related variables between the two examiners was calculated on 10 patients having 23 implants. It resulted in a high degree of agreement for the vestibular KTH (ICC=0.88; $p < 0.001$); in a substantial agreement for the deepest PPD (ICC=0.69; $p < 0.001$), the presence of PISTD (agreement=86.36%; kappa=0.70; $p < 0.001$) and the prosthetic design allowing access to hygiene (agreement=95.65%; kappa=0.78; $p < 0.001$); in a moderate agreement for the tissue thickness (ICC=0.56; $p = 0.001$) and the peri-implant phenotype (agreement=91.30%; kappa=0.45; $p = 0.015$) (Landis & Koch, 1977).

Periapical digital radiographs of the included implants were taken and the marginal bone level (BL) (linear measurement from the implant shoulder to the first bone-implant contact) was measured by one calibrated investigator (CL), using a software program (Autocad 2016 TM, AutoDesk Inc., San Rafael, CA, USA) (Flores-Guillen et al., 2018). 50 randomly selected radiographs were re-measured by the same investigator, achieving a high degree of intra-examiner agreement (ICC=0.98; 95% CI 0.96–0.99; $p < 0.001$). In addition to the assessment of peri-implant bone levels, the following parameters were recorded from the periapical radiographs: presence of prosthesis abutment, gap or step, the maximum crown height, the presence of residual cement, the emergence angle and profile (Katafuchi et al., 2018), the presence of mesial or distal cantilever and the presence of platform switching.

Original dental charts for each of the included implants were also analysed to extract data on the implant brand and the implant dimensions (length, width and eventual collar length). If the original information was not available (i.e. lost dental chart or implant placed outside the clinic), we attempted to infer the corresponding information from the radiographies (Romandini et al., 2021b). A validation of this method was performed on thirty randomly selected implants of known dimensions, which resulted in an ICC for implant length of 0.95 (95% CI 0.89–0.97; $p < 0.001$).

2.3 | Peri-implant buccal soft tissue dehiscence case definitions

The PISTD depth was measured in mm when there was exposure either of the prosthetic abutment or of the implant neck or the implant surface (Sanz-Martín et al., 2021). For the present study, only buccal PISTD were considered, defined as the presence of a mucosal dehiscence in at least one buccal site. Implants located in molar sites were excluded. Two different types of buccal PISTD were identified, either in implants affected or not by peri-implantitis (according to the Sanz & Chapple, 2012 case definition, validated in Romandini et al., 2021) (Figures 1-2).

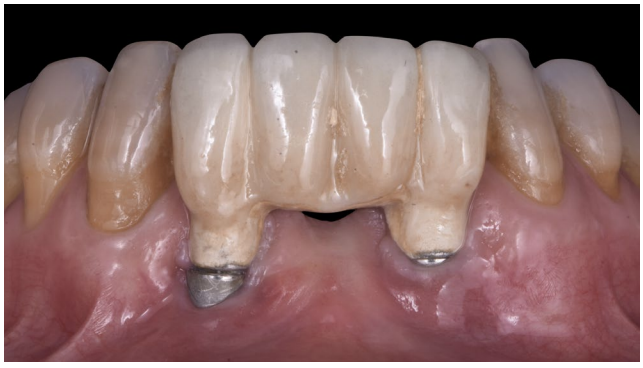

FIGURE 1 Peri-implant soft tissue dehiscence in implants not affected by peri-implantitis

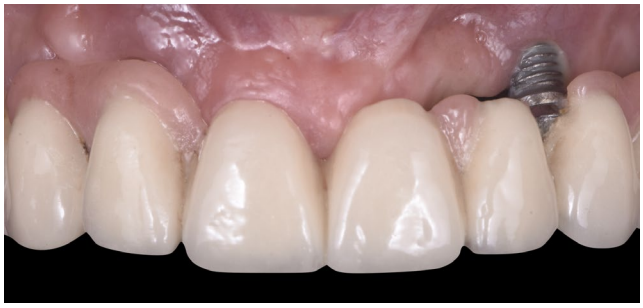

FIGURE 2 Peri-implant soft tissue dehiscence in an implant affected by peri-implantitis

2.4 | Data analysis

All statistical analyses were performed with STATA version 13.1 software (StataCorp LP, College Station, TX, USA). Descriptive characteristics regarding all the covariates were summarized. Buccal PISTD prevalence was calculated both at patient- and at implant-level, according to different severity cut-offs (>0 mm, >1 mm and >2 mm). The participants perception about buccal PISTD was evaluated comparing the OHIP-14 sum score and the aesthetic self-evaluation of implant rehabilitations (VAS) between subjects affected and not affected by PISTD (all types), using the Mann–Whitney two-sample test. Risk/protective indicators for buccal PISTD in implants not suffering peri-implantitis were then studied using multilevel (mixed-effects) multivariate logistic regression analysis (patient- and implant-level). Due to the paucity of information on true risk factors available in literature, an exploratory approach was used. Each potential indicator was tested individually by adding it to an empty model having as dependent variable the buccal PISTD status and assessing its statistical significance. All variables that were significant at the 0.10 level were included in an intermediate multilevel multivariate model, and non-significant variables were sequentially removed. On that model which included all factors that remained significant ($p < 0.05$), the non-significant indicators were tested again and the significant ones were retained in the final model.

3 | RESULTS

The sampling strategy resulted in the selection of 240 subjects and 109 of them accepted to participate receiving the examination. From this initial sample, one patient was excluded as only presenting one implant loaded from less than 1 year, while another patient was excluded due to the loss of all the implants. Moreover, 237 implants were excluded because located in the molar position, resulting in the exclusion of 15 patients not presenting any anterior implant. Consequently, the present analysis included a total of 92 patients with 272 dental implants.

3.1 | Descriptive statistics of the study population and implants

Table 1 and Table 2 provide descriptive statistics of the study population and implants. Most of the included participants were women (60.9%), currently non-smokers (83.7%), with moderate/severe periodontitis (62.2%) and with a mean age at examination of 64.2 years. More implants were placed in the maxilla (65.4%), rehabilitated by multi-unit fixed partial prosthesis (65.4%) and screw-retained prosthesis (58.1%). The prevalence of peri-implantitis in this sample was 41.3% at patient-level and 27.6% at implant-level.

TABLE 1 General characteristics of the study population

	N = 92
Age (years), mean (SD)	64.2 (9.8)
Gender, N (%)	
Male	36 (39.1)
Female	56 (60.9)
Educational Level, N (%)	
Primary school	30 (32.6)
High school	24 (26.1)
Middle grade	19 (20.7)
University/College	19 (20.7)
Smoking Status, N (%)	
Non-smokers	43 (46.7)
Former smokers	34 (37.0)
Current smokers	15 (16.3)
Marital Status, N (%)	
Married	68 (73.9)
Widow	6 (6.5)
Divorced	9 (9.8)
Never married	6 (6.5)
Living with unmarried partner	3 (3.3)
BMI (kg/m^2), mean (SD)	25.6 (3.8)
Diabetes Status, N (%)	
No diabetes	80 (87.0)
Diabetes	12 (13.0)
Periodontal Status (AAP), N (%)	
No/Mild Periodontitis	24 (26.6)
Moderate/Severe Periodontitis	56 (62.2)
Edentulous	10 (11.1)
Regular Maintenance, N (%)	
No	41 (44.6)
Less than one/year	7 (7.6)
One/year	21 (22.8)
Two/year	20 (21.7)
Three or more/year	3 (3.3)
Peri-implant Status, N (%)	
Peri-implant health	2 (2.17)
Peri-implant mucositis	15 (16.3)
Pre-peri-implantitis	26 (28.3)
Peri-implantitis	38 (41.3)
Unknown	11 (11.9)

Note: Total number varies according to missing data for each variable.
Abbreviations: SD, standard deviation; N, number.

3.2 | Prevalence and severity of buccal PISTD

The prevalence and severity of buccal PISTD is reported in Table 3. At patient-level, the prevalence of buccal PISTD was 26.1%, while it was 15.8% when considering only implants without peri-implantitis.

TABLE 2 General characteristics of the study implants

	N = 272
Jaw, N (%)	
Maxilla	178 (65.4)
Mandible	94 (34.6)
Side, N (%)	
Right	141 (51.8)
Left	131 (48.2)
Type of Prosthesis, N (%)	
Single crown	
Bridge	178 (65.4)
Overdenture	43 (15.8)
Full-arch fixed restoration	51 (18.8)
Prosthesis Retention, N (%)	
Cemented	68 (25.0)
Screw-retained	158 (58.1)
Locator	14 (5.2)
Bar	32 (11.7)
Reason of Tooth Loss, N (%)	
Caries	113 (41.5)
Periodontitis	145 (53.3)
Trauma	10 (3.7)
Agenesia	4 (1.5)
Other reason/Unknown	
Implant Brand, N (%)	82 (30.2)
S	106 (39.0)
N	15 (5.5)
A	6 (2.2)
Other	63 (23.1)
Implant Length (mm), mean (SD)	10.00 (1.7)
Implant Diameter (mm), mean (SD)	4.1 (0.4)
Peri-implant Status, N (%)	
Peri-implant health	25 (9.2)
Peri-implant mucositis	73 (26.8)
Pre-peri-implantitis	69 (25.4)
Peri-implantitis	75 (27.6)
Unknown	30 (11.0)

Note: Total number varies according to missing data for each variable.
Implant brands: S, Straumann; N, Nobel Biocare; A, AstraTech.
Abbreviations: N, number; SD, standard deviation.

In patients diagnosed with peri-implantitis, the 29.3% had at least one of those implants with a buccal PISTD.

At implant-level, the prevalence of buccal PISTD was 16.9%, while 12.0% when considering only implants without peri-implantitis. In implants with peri-implantitis, the 26.7% of the implants had a buccal PISTD. Severe cases of buccal PISTD (>2 mm) were a seldom finding, affecting only 6.5% and 2.9% of the population, respectively, of patients and implants. In implants without peri-implantitis, severe PISTD affected 1.3% of the patients and 0.6% of the implants, while

TABLE 3 Prevalence of PISTD

	Patient-level				Implant-level			
	Buccal PISTD	Buccal PISTD in implants without PI*	Buccal PISTD in implants with PI*	Buccal PISTD in implants with unknow peri-implant health	Buccal PISTD	Buccal PISTD in implants without PI*	Buccal PISTD in implants with PI*	Buccal PISTD in implants with unknow peri-implant health
No PISTD, N (%)	68 (73.9)	64 (84.2)	29 (70.7)	8 (72.7)	226 (83.1)	147 (88.0)	55 (73.3)	24 (80.0)
PISTD, N (%)								
>0 mm	24 (26.1)	12 (15.8)	12 (29.3)	3 (27.3)	46 (16.9)	20 (12.0)	20 (26.7)	6 (20.0)
>1 mm	11 (12.0)	4 (5.3)	7 (17.1)	1 (9.1)	19 (7.0)	8 (4.8)	9 (12.0)	2 (6.7)
>2 mm	6 (6.5)	1 (1.3)	4 (9.8)	1 (9.1)	8 (2.9)	1 (0.6)	6 (8.0)	1 (3.3)

Abbreviations: N, number; PI, peri-implantitis.
*Corresponding to the Sanz and Chapple (2012) peri-implantitis case definition.

TABLE 4 Patient perception about buccal PISTD

Patient perception	Overall (N = 92)	No buccal PISTD (N = 68)	Buccal PISTD (N = 24)	*p*-value
OHIP–14 Total, mean (SD)	7.81 (6.22)	8.29 (6.40)	6.45 (5.59)	$p = 0.246$
Self-perceived implant rehabilitation aesthetics (VAS), mean (SD)	78.08 (21.84)	78.72 (21.40)	76.27 (23.43)	$p = 0.630$

Abbreviations: N, number of subjects; SD, standard deviation, VAS, visual analogue scale.

in implants with peri-implantitis it affected, respectively, 9.8% and 8.0% of them.

3.3 | Participants perception about buccal PISTD

Table 4 depicts the participants perception about buccal PISTD. The mean OHIP-14Sp sum score was 7.81 (SD=6.22), indicating a low level of oral health-related impairment. The mean VAS score for the self-perceived aesthetics of the implant rehabilitations was 78.08 (SD=21.84), indicating a moderately high level of aesthetic satisfaction. No statistically significant differences were observed for both OHIP-14Sp and self-perceived aesthetics of the implant rehabilitations between subjects affected and not affected by buccal PISTD.

3.4 | Risk/protective indicators for buccal PISTD in implants without peri-implantitis

The distribution of the potential risk/protective indicators in the studied patients/implants in regard to their buccal PISTD status is reported in Tables S1 and S2. Patient- and implant-level variables resulted in the univariate analyses as risk/protective indicators of buccal PISTD in implants without peri-implantitis are reported in Tables S3 and S4.

In the final multilevel multivariate logistic regression model (Table 5), the malposition (too buccal vs. correct: OR=14.67) and the thin peri-implant phenotype (OR=8.31) were identified as risk indicators for the presence of buccal PISTD in implants without peri-implantitis. Conversely, the presence of at least one adjacent tooth (OR=0.08) and of an abutment (OR=0.12) were identified as protective ones.

4 | DISCUSSION

The present study on a representative sample of patients treated in a university clinic has shown how buccal PISTD in anterior implants are highly prevalent. More than 25% of the participants had a buccal PISTD in at least one anterior implant. When excluding implants with peri-implantitis, 15% of the participants had a buccal PISTD in the anterior zone. PISTD had a prevalence more than double in implants with peri-implantitis than in implants without peri-implantitis. Severe buccal PISTD in the anterior zone was a rare finding, since it affected 7% of the participants and 3% of the implants. Besides their high prevalence, the impact of buccal PISTD on oral health-related quality of life and on self-perceived aesthetics was null. Mainly local factors were identified as risk/protective indicators of buccal PISTD in implants without peri-implantitis, with the implant malposition and the peri-implant phenotype resulting as the ones with increased risk. In particular, implants placed too buccally resulted in an odds ratio of 14.7 to be affected by buccal PISTD.

Since most of the available data are restricted to convenience samples rehabilitated with specific protocols, a thorough comparison of the prevalence and severity of PISTD reported in this investigation is not possible. In these studies, higher prevalence of PISTD has been reported in anterior maxillary implants (Nisapakultorn et al., 2010) and also when implants were placed using immediate implant placement protocols (Cosyn et al., 2016). In contrast, a lower prevalence has been reported in patients rehabilitated with overdentures (Romandini et al., 2019). These differences may be easily explicable by the different population characteristics and case definitions employed. The prevalence of buccal PISTD found in the present study is lower than the one reported for gingival recessions around teeth in adults (Susin et al., 2004; Sarfati et al., 2010; Rios et al., 2014; Serrano et al., 2018; Romandini et al., 2020). This finding may be explained by the higher number of teeth present for longer periods of time in the mouths, when compared with implants. However, when comparing the patient-level prevalence of buccal PISTD in implants without peri-implantitis with the one of RT1 gingival recessions ≧1 mm, they appear to be similar (10–15%), suggesting a comparable manifestation of these two apparently similar conditions (Romandini et al., 2020). [Correction added on 24 December 2021, after first online publication: The duplicate sentence in this paragraph has been deleted in this version.]

To the best of our knowledge, no previous studies evaluated the patient perception about buccal PISTD. The null impact observed on both oral health-related quality of life and self-perceived aesthetics may possibly be explained by the characteristics of the present population, which was extrapolated from a university periodontal clinic. As a consequence, it was characterized mostly by elderly participants, with low–medium socioeconomic status and mostly affected by moderate/severe periodontitis or edentulous.

TABLE 5 Risk/protective indicators associated with the presence of PISTD in implants without peri-implantitis: multilevel multivariate logistic regression analysis

	Buccal PISTD in implants without PI*					
	Null Model			Final Model		
Variable	OR	95% CI	*p*-value	OR	95% CI	*p*-value
Fixed part						
Intercept	0.02	0.00–0.17	0.000	1.15	0.38–3.51	0.798
Vestibular-Lingual Position						
Correct				Ref	Ref	Ref
Too Buccal				14.67	2.12–101.55	0.006
Too Lingual				NE	NE	NE
Peri-implant phenotype						
Thick				Ref	Ref	Ref
Thin				8.31	1.75–39.41	0.008
Presence of Adjacent Tooth						
No				Ref	Ref	Ref
Yes				0.08	0.02–0.36	0.001
Abutment, N (%)						
No				Ref	Ref	Ref
Yes				0.12	0.02–0.71	0.020
Random part						
Patient variance	5.86	1.26–2.29		0.28	0.00–197.06	
AIC	109.34			76.57		

Note: The estimate of $\sigma 2$ was 0.28 with standard error (*SE*) A likelihood-ratio test comparing the model to ordinary logistic regression was performed and it resulted as highly significant ($p < 0.001$). The intra-class correlation (ICC) at the patient-level showed that 64.0% (ICC 0. 0.64; 95% CI 0.28–0.89) of the correlation was due to variation among patients and 46.0% due to variations among implants.

Abbreviations: OR, odds ratio; CI, confidence interval; Ref, reference category; AIC, Akaike´s information criterion.

*Corresponding to the Sanz and Chapple (2012) peri-implantitis case definition.

When it comes to risk/protective indicators, the present study was able to identify several factors associated with buccal PISTD in implants without peri-implantitis. Single implants placed too buccally in the anterior zone have been previously associated with an increased risk of experiencing PISTD (Evans & Chen, 2008; Cosyn et al., 2012), which was confirmed in a recent case–control study (Sanz-Martín et al., 2021) and it is in the same direction of the present data. Similarly, the peri-implant phenotype has previously already shown to be another important predisposing factor, being thin phenotypes associated with PISTD in single implants placed in the anterior maxilla (Evans & Chen, 2008; Nisapakultorn et al., 2010; Kan et al., 2011). Both factors (tooth malposition and tissue thickness) have been also implicated as risk indicators for RT1 gingival recessions around teeth (Cortellini & Bissada, 2018).

The presence of at least one adjacent tooth as protective indicator for PISTD in implants without peri-implantitis has been already pointed out (Sanz-Martín et al., 2021). We may speculate that the presence of a tooth adjacent to the implant, through its periodontal attachment, may contribute to maintain the soft tissue height at the implant site and thus reduce the risk of PISTD, even if no association was found in the present study in relation with the interproximal CAL of the adjacent teeth. Another possible explanation is that the presence of adjacent teeth may guide the surgeon in the correct three-dimensional implant placement. Finally, the presence of an abutment (i.e. angulated) may allow prosthetic corrections of mispositioned implants, which may potentially explain its role as protective indicator for PISTD. Moreover, it may also be speculated that implants positioned too coronally may be at higher risk of PISTD and—at the same time—they may not allow the placement of an abutment, providing an additional potential mechanism to explain this emerged association.

The results of the present investigation are relevant, due to the lack of similar representative studies reporting the prevalence, the severity and the risk/protective indicators of buccal PISTD while minimizing the risk of selection bias. However, this study also has some limitations, including its cross-sectional design, the limited (moderate) inter-rater agreement for the assessment of tissue thickness and peri-implant phenotype, the potential lack of statistical

power for some risk indicators and the lack of information about others (i.e. surgical protocols, vertical positioning of the implants). In particular, the cross-sectional design does not allow to prove any causality and prevents the recognition of buccal PISTD in presence of long crowns (lack of a reference). However, despite that, some of the factors that may influence the development of buccal PISTD cannot be evaluated prospectively in clinical trials due to ethical reasons (Sanz-Martín et al., 2021). Finally, even if representative from a university clinic, the present results may suffer from limited external validity.

5 | CONCLUSIONS

According to the present study, buccal PISTD are highly prevalent among patients with dental implants. Several implant-level factors were identified as risk and protective indicators of buccal PISTD in implants without peri-implantitis which, in case causality is proved, should be included in preventive strategies. Consequently, randomized clinical trials or, when not possible for ethical reasons or as not modifiable, prospective cohort studies are needed to demonstrate true causality of the identified risk/protective indicators and/or to study the preventive efficacy of their modification.

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CONFLICT OF INTEREST

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

AUTHOR CONTRIBUTIONS

M.R. conceived the ideas; C.L., I.P., A.A., M.C.S. and M.R. collected the data; M.R., M.C.S. and M.S. analysed the data; and M.R. and M.S. led the writing.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

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

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