

Research Article

A Retrospective Analysis of Biological Complications of Dental Implants

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Background and Objective. Several risk factors have been implicated in onset and development of peri-implant diseases. The impact of these factors, however, remains controversial across the different clinical settings and populations. The aim of this retrospective study was to evaluate the risk factors for peri-implant diseases among an Emirati population. **Methods.** A retrospective analysis of patients aged ≥ 18 years and having dental implants placed at Dubai Health Authority in 2010. Relevant information related to systemic-, patient-, implant-, site-, surgical- and prosthesis-related factors were collected. The strength of association between the prevalence of peri-implant mucositis and peri-implantitis and each variable was measured by chi-square analysis. A binary logistic regression analysis was performed to identify possible risk factors. **Results.** A total of 162 patients with 301 implant-supported restorations were included in the study. The age of the patients ranged between 19 and 72 with a mean age of 46.4 ± 11.7 years. The prevalence of peri-implant mucositis at the patient and implant levels were 44.4% and 38.2%, respectively. For peri-implantitis, the prevalence at the patient level was 5.6%, while the prevalence at the implant level was 4.0%. The binary logistic regression identified three risk factors (smoking habits, histories of treated periodontitis and lack of peri-implant maintenance) for peri-implantitis. **Conclusion.** Within the limitations of this study, smoking habits, history of treated periodontitis and lack of peri-implant maintenance were significant risk factors for peri-implantitis. Early detection of these factors would ensure appropriate planning and care of patients at high risk of developing peri-implant diseases.

1. Introduction

In the replacement of missing teeth, treatment outcomes with fixed dental prostheses are associated with technical and biological complications in the long term. With dental implants, biological and technical complications were observed in 33.6% of patients during a 5-year follow-up period [1]. Biological complications of dental implants, (i.e. peri-implant mucositis and peri-implantitis) can negatively impact the longevity of dental implants leading to implant

failure [2–4]. Peri-implant mucositis is defined as an inflammatory lesion of the mucosa surrounding a functionally osseointegrated dental implant while peri-implantitis is a progressive inflammatory disease affecting the peri-implant bone [5].

Peri-implant disease classification, case definition, and diagnostic criteria set to define peri-implant diseases, however, remain highly controversial [6–9]. These variations have made the assessment of the true prevalence of peri-implant diseases and associated risk factors very arduous

[10, 11]. For example, a prevalence of 46.8% and 19.8% at the patient level were reported for peri-implant mucositis and peri-implantitis, respectively [12], while other reviews, estimated the equivalent at 64.3% and 18.8%, respectively [5, 13]. On the other hand, several risk factors were implicated in the onset and development of peri-implantitis [14]. For instance, patient-related risk factors such as inadequate plaque control, smoking, history of periodontitis, and lack of regular periodontal maintenance were identified in several retrospectives and cross-sectional studies [15]. Systemic-related risk factors such as diabetes mellitus [16] and factors related to implant design or surface characteristics were also described [17]. The need to identify risk factors associated with the onset and progression of peri-implant diseases for clinicians to set up effective preventive and maintenance regimens cannot be over-emphasized. These programs should be based on unequivocal case definitions and quality reporting of peri-implant disease prevalence [8]. The aims of the present study, therefore, were to evaluate the prevalence of peri-implant diseases and identify systemic-, patient-, implant-, site-, surgical- and prosthesis-related risk factors associated with the onset of peri-implant diseases.

2. Materials and Methods

2.1. Study Design and Participants. This was a retrospective study that included patients aged ≥ 18 years and having dental implants placed at Dubai Health Authority (DHA) in 2010. All the patients had periodontal and radiographic assessment prior to dental implant placement and during the follow-up visits up to 2019. The patients were advised to follow a regular maintenance program every six months with a hygienist. The patient records at DHA included demographic data, medical and dental history as well as the number of follow-up and maintenance visits. The current study was prepared in compliance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [18].

2.2. Inclusion Criteria. The following are the criteria: aged ≥ 18 years; had dental implants placed at DHA in 2010; had sufficient record of clinical parameters and radiographic examination at each follow-up visit; had maintained a stable periodontal health during the follow-up period.

2.3. Exclusion Criteria. Records with missing data on more than 50% of the follow-up time were excluded.

2.4. Ethical Approval. The study was approved by the DHA and the institutional review board of Mohammed Bin Rashid University of Medicine and Health Sciences (MBRU-IRB-2020-014) in accordance with the Declaration of Helsinki of ethical human research practice.

2.5. Data Collection. Data were collected by one of the investigators (Z.A.) using dental practice management

software (D4W, Australia), Salama software, and explanted implant records available at DHA. A standardized data collection form was used to collect relevant information. The data were collated into four main domains:

- (i) Demographic data.
- (ii) Systemic and patient-related outcomes.
- (iii) Implant-, site-, and surgical-related outcomes.
- (iv) Prosthesis-related outcomes.

Patients were not recalled for examination. The information related to the clinical assessment, implant system, and radiographic marginal bone level changes were obtained from patient records. Data collection was divided into several sub-categories: systemic-related factors such as medical and social history, which were assessed at the time of implant placement. Implant-, surgical- and prosthesis-related factors such as implant system, location, surface roughness, height, diameter, shape, placement protocol, number of functional years prior to peri-implant diseases, use of grafting materials at the time of implant placement, type of retention, screw loosening, number of maintenance visits were also collected and analyzed as possible risk factors for peri-implantitis.

2.6. Systemic- and Patient-Related Factors

- (i) Gender.
- (ii) Systemic conditions.
- (iii) Diabetes Mellitus.
- (iv) Dyslipidemia.
- (v) Hypertension.
- (vi) Osteoporosis.
- (vii) Anemia.
- (viii) Hypothyroidism.
- (ix) Smoking habits.
- (x) Parafunctional habits.
- (xi) History of treated periodontitis.
- (xii) Lack of regular dental attendance (regular attendance was defined as at least one dental check-up per year).
- (xiii) Lack of regular peri-implant maintenance (regular maintenance was defined as at least one dental visit for peri-implant maintenance per year).

2.7. Implant- And Site-Related Factors

- (i) Implant system (implant surface characteristics).
- (ii) Implant shape.
- (iii) Implant height.
- (iv) Implant diameter.
- (v) Implant location.
- (vi) Implant placement protocols [19].
- (vii) Use of grafting material at the time of implant placement.
- (viii) Operator.

2.8. Prosthesis-Related Factors

- (i) Type of prosthesis.
- (ii) Suprastructure retention.
- (iii) Number of functional years prior to diagnosis.
- (iv) Prosthetic complications: screw loosening.
- (v) Prosthetic complications: crown chipping.
- (vi) Prosthetic complications: crown debonding.

Records with missing data on more than 50% of the follow-up time were excluded.

2.9. Case Definition. Peri-implant mucositis was defined as an osseointegrated functional implant that demonstrated bleeding and/or suppuration on probing, absence of increasing probing depths, and bone loss beyond initial remodeling of crestal bone levels. Peri-implantitis was defined as an osseointegrated functional implant that demonstrated bleeding and/or suppuration on probing, increased probing depths and bone loss beyond initial remodeling of crestal bone levels or >2 mm in the absence of baseline clinical parameters. A healthy implant was defined as one which showed no clinical signs of inflammation, absence of increased probing depths and bone loss beyond initial remodeling of crestal bone levels [7, 20].

2.10. Reliability Study. An experienced clinician (M.A.) conducted a training session on data collection which included running a practice exercise using a predetermined collection form from an actual patient file. To produce stable and consistent results, an intra-examiner reliability tests were performed by selecting five files from a pool of retrieved patient files. Data were collected by the investigator (Z.A.) two weeks apart and cross-checked by an experienced clinician (M.A.). The strength of intra-examiner reliability was assessed by calculating Cohen's kappa coefficients for selected items with two or more categories. Kappa scores of 0.21–0.40 indicated fair reliability; 0.41–0.60 indicated moderate reliability; 0.61–0.80 indicated substantial reliability; and 0.81–1.0 indicated excellent reliability [21].

2.11. Power Analysis. The determination of the sample size needed was based on adopting 95% power and 5% error using G * power software (version 3.1.9.4). A representative sample size of 262 implants was calculated for the inclusion of at least 15 risk factors. To account for possible exclusions, a total of 300 implants were included.

2.12. Statistical Analyses. Data were analyzed using SAS statistical software version 9.4. The strength of association between the prevalence of peri-implant diseases and each variable was measured by exact chi-square analysis. Differences were considered statistically significant at $p < 0.05$. Estimates of relative risk were also calculated for all variables. For systemic and patient-related factors, the patient was considered the unit of analysis. Therefore, only one

event of peri-implant mucositis or peri-implantitis per patient was included in the analysis to enhance statistical accuracy [22]. For implant-, site-, and prosthesis-related factors, the implant was considered as the statistical unit.

Risk factors for peri-implantitis were estimated by a binary logistic regression, which is the appropriate model for a categorical dichotomous outcome (peri-implantitis was coded 0 if no events occurred and 1 if peri-implantitis was reported). A backward stepwise method was selected. All predictor variables which had p values of less than 0.05 or a relative risk of 1.5 or greater were entered into the analysis and coded in a binary format of 0 or 1. Then, at each step, the variable with a significance level equal to or larger than 0.05 was removed, until the final model was obtained.

3. Results

A total of 162 patients with 301 implant-supported restorations were included in the study. The age of the patients ranged between 19 and 72 with a mean age of 46.4 ± 11.7 years. The prevalence of peri-implant mucositis at the patient and implant levels were 44.4% and 38.2%, respectively. For peri-implantitis, the prevalence at the patient level was 5.6%, while the prevalence at the implant level was 4.0%. The kappa values for the intra-examiner agreement ranged between 0.88 and 0.94, indicating excellent agreement in the data collection.

3.1. Peri-Implant Mucositis. Patients diagnosed with peri-implant mucositis were more likely to be irregular attenders of peri-implant maintenance visits as 55.4% of irregular attenders were diagnosed with peri-implant mucositis compared to 35.2% of regular attenders diagnosed with peri-implant mucositis ($p = 0.012$). There was, however, no significant association between history of treated periodontitis or lack of regular dental attendance and peri-implant mucositis. Gender, presence of any systemic conditions, smoking and parafunctional habits had no significant impact on the prevalence of peri-implant mucositis (Table 1). All implants placed were roughened-surface Ankylos, Xive or Friadent implants with grit-blasted, acid-etched implant surfaces (Friadent plus, Dentsply Sirona), hence, it was not possible to compare the impact of implant surface characteristics on the prevalence of peri-implant mucositis. Cement-retained single crown implant restorations were more likely to be associated with an increased prevalence of peri-implant mucositis. However, the difference was not statistically significant when compared with screw-retained restorations. The implant dimension, implant location, implant placement protocol, use of grafting materials, operator or any prosthesis-related factors did not have any significant influence on the prevalence of peri-implant mucositis (Table 2).

3.2. Peri-Implantitis. The prevalence of peri-implantitis was statistically significant among smokers, those with a history of treated periodontitis and patients who did not attend regular peri-implant maintenance visits. Gender, presence of

TABLE 1: Characteristics of patients diagnosed with peri-implant mucositis ($n = 162$).

Systemic and patient-related factors:	<i>N</i> (%) diagnosed peri-implant mucositis	Relative risk (95% CI)	<i>p</i> value*
Gender			
Male	34 (52.3)	1.34 (0.95, 1.88)	0.109
Female	38 (39.2)		
Presence of systemic conditions			
Yes	22 (43.1)	1.04 (0.72, 1.52)	0.866
No	50 (45.0)		
Presence of diabetes mellitus			
Yes	15 (51.7)	0.83 (0.55, 1.24)	0.415
No	57 (42.9)		
Presence of dyslipidemia			
Yes	7 (50.0)	0.88 (0.50, 1.53)	0.781
No	65 (43.9)		
Presence of hypertension			
Yes	10 (43.5)	1.03 (0.62, 1.70)	1.000
No	62 (44.6)		
Presence of osteoporosis			
Yes	1 (14.3)	3.21 (0.52, 19.84)	0.133
No	71 (45.8)		
Presence of anemia			
Yes	2 (50.0)	0.89 (0.33, 2.40)	1.000
No	70 (44.3)		
Presence of hypothyroidism			
Yes	3 (37.5)	1.20 (0.48, 2.97)	0.734
No	69 (44.8)		
Smoking habits			
Smokers	10 (43.5)	1.01 (0.61, 1.67)	1.000
Non-smokers	60 (43.8)		
Parafunctional habits			
Yes	2 (18.2)	2.55 (0.72, 9.04)	0.114
No	70 (46.4)		
History of treated periodontitis			
Yes	20 (50.0)	0.85 (0.59, 1.24)	0.466
No	52 (42.6)		
Lack of regular dental attendance			
Yes	16 (55.2)	1.31 (0.89, 1.92)	0.221
No	56 (42.1)		
Lack of regular peri-implant maintenance			
Yes	41 (55.4)	1.57 (1.11, 2.23)	0.012
No	31 (35.2)		

CI: confidence interval. *Exact chi-square test.

any systemic conditions, parafunctional habits, and lack of regular dental attendance had no significant impact on the prevalence of peri-implantitis (Table 3). Likewise, implant-, site-, surgical- and prosthesis-related factors did not have any significant influence on the prevalence of peri-implantitis (Table 4).

The binary logistic regression showed that smoking habits, history of treated periodontitis, and lack of peri-implant maintenance had a statistically significant association with the onset of peri-implantitis in the final model. The three variables had low standard errors implying a statistically stable model and did not contain a value of 1.00 representing useful and independent predictor variables. The odds ratios showed that smokers, those with a history of treated periodontitis, and those who did not attend regular peri-implant maintenance were eight, seven, and ten times at

risk of peri-implantitis, respectively. The overall accuracy of the model to predict peri-implantitis (with a predicted probability of 0.5 or greater) was 96.3%. The estimates of the logistic regression model, the adjusted odds ratios for the three risk factors and their 95% CIs are summarized in Table 5.

4. Discussion

The present study reports on the prevalence rates of peri-implant mucositis and peri-implantitis and associated risk factors over a 10-year follow-up period. The prevalence rates for peri-implant mucositis were 44.4% and 38.0% at patient and implant levels, respectively. The corresponding rates for peri-implantitis were 5.6% and 4.0% at patient and implant levels, respectively.

TABLE 2: Characteristics of implants diagnosed with peri-implant mucositis ($n = 301$).

Implant-, site-, and surgical-related outcomes	<i>N</i> (%) diagnosed peri-implant mucositis	Relative risk (95% CI)	<i>p</i> value*
Implant system			
Ankylos	48 (38.7)	NA	0.458
Xive	66 (39.1)		
Friadent	0 (0.0)		
Implant shape			
Cylindrical	48 (38.7)	1.01 (0.75, 1.35)	1.000
Tapered	66 (38.4)		
Implant height (mm)			
<11	72 (38.9)	0.97 (0.72, 1.30)	0.903
≥11	43 (37.7)		
Implant diameter (mm)			
<4.5	65 (39.4)	0.95 (0.71, 1.27)	0.722
≥4.5	50 (37.3)		
Implant location			
Anterior maxilla	8 (25.0)	NA	0.308
Posterior maxilla	40 (36.7)		
Anterior mandible	4 (50.0)		
Posterior mandible	63 (41.4)		
Implant placement protocol			
Type I	7 (43.8)	NA	0.580
Type II	3 (30.0)		
Type III	6 (26.1)		
Type IV	99 (39.3)		
Bone augmentation procedure at the time of implant placement			
Yes	21 (34.4)	1.14 (0.78, 1.67)	0.50
No	94 (39.2)		
Operator			
Periodontist	76 (39.8)	0.89 (0.66, 1.21)	0.463
Oral and maxillofacial surgeon	39 (35.5)		
Prosthesis-related outcomes			
Type of prosthesis			
Single implant crown	96 (40.3)	1.34 (0.89, 2.01)	0.148
Multiple-unit implant-supported prosthesis	19 (30.2)		
Superstructure retention			
Screw-retained	40 (35.7)	0.91 (0.67, 1.23)	0.538
Cement-retained	71 (39.4)		
Number of functional years prior to diagnosis			
<5 years	59 (43.1)	1.26 (0.95, 1.68)	0.123
≥5 years	56 (34.1)		
Prosthetic complications			
Screw loosening			
Yes	11 (40.7)	0.93 (0.58, 1.50)	0.837
No	104 (38.0)		
Crown chipping			
Yes	5 (33.3)	1.15 (0.56, 2.40)	0.790
No	110 (38.5)		
Crown debonding			
Yes	18 (38.3)	1.00 (0.67, 1.48)	1.000
No	97 (38.2)		

CI: confidence interval. *Exact chi-square test.

TABLE 3: Characteristics of patients diagnosed with peri-implantitis ($n = 162$).

Systemic and patient-related factors:	N (%) diagnosed peri-implantitis	Relative risk (95% CI)	p value*
Gender			
Male	2 (3.1)	0.43 (0.09, 1.99)	0.317
Female	7 (7.2)		
Presence of systemic conditions			
Yes	3 (5.9)	0.92 (0.24, 3.53)	1.000
No	6 (5.4)		
Presence of diabetes mellitus			
Yes	2 (6.9)	0.76 (0.17, 3.49)	1.000
No	7 (5.3)		
Presence of dyslipidemia			
Yes	1 (7.1)	0.76 (0.10, 5.62)	1.000
No	8 (5.4)		
Presence of hypertension			
Yes	1 (4.3)	1.32 (0.17, 10.09)	1.000
No	8 (5.8)		
Presence of osteoporosis			
Yes	1 (14.3)	0.36 (0.05, 2.50)	0.335
No	8 (5.2)		
Presence of anemia			
Yes	1 (25.0)	0.20 (0.03, 1.26)	0.206
No	8 (5.1)		
Presence of hypothyroidism			
Yes	1 (12.5)	0.42 (0.06, 2.93)	0.374
No	8 (5.2)		
Smoking habits			
Smokers	5 (21.7)	9.24 (2.26, 37.60)	0.003
Non-smokers	4 (2.9)		
Parafunctional habits			
Yes	1 (9.1)	0.58 (0.08, 4.25)	1.000
No	8 (5.3)		
History of treated periodontitis			
Yes	6 (15.0)	7.00 (1.66, 29.47)	0.008
No	3 (2.5)		
Lack of regular dental attendance			
Yes	1 (3.4)	0.57 (0.07, 4.41)	0.701
No	8 (6.0)		
Lack of regular peri-implant maintenance			
Yes	8 (10.8)	9.51 (1.22, 74.33)	0.012
No	1 (1.1)		

CI: confidence interval. *Exact chi-square test.

The prevalence of peri-implant mucositis reported in the present study was higher than previously reported [23] where the estimated prevalence of peri-implant mucositis was 20.2% at the patient level and 10.2% at the implant level. The present results, however, were comparable with other studies [24, 25]. In one study [25] with a total of 4591 implants and a follow-up period of 5 to 10 years, the estimated prevalence of peri-implant mucositis was 38.6% at the implant level, while that of peri-implantitis was 4.7%. Similarly, a cross-sectional study of 24 of 96 patients with 225 implants and a follow-up period of 11 years reported a prevalence rate of 48% for peri-implant mucositis at the patient level and 33% at the implant level. On the other hand, the prevalence rate for peri-implantitis reported in the present study was higher than those reported previously, at both the patient and implant levels. The observed differences

in results amongst the different studies could be a reflection of the differences in the study designs and the clinical and radiographic criteria used for diagnosing peri-implant diseases. It is well documented that using different thresholds of severity in reporting prevalence of peri-implantitis results in a wide range of peri-implantitis prevalence rates [10, 26]. In this context, our study adopted the definition of the 2017 World Workshop [7, 20] to allow comparability with other future studies.

4.1. Systemic- And Patient-Related Factors. The present review has shown that lack of regular peri-implant maintenance was a significant risk factor for the development of peri-implant diseases as patients who did not undergo regular peri-implant maintenance were at ten times higher risk of peri-implantitis. This significant association is in

TABLE 4: Characteristics of implants diagnosed with peri-implantitis ($n = 301$).

Implant-, site-, and surgical-related outcomes	<i>N</i> (%) diagnosed peri-implantitis	Relative risk (95% CI)	<i>p</i> value*
Implant system			
Ankylos	6 (3.6)	NA	0.794
Xive	6 (4.8)		
Friadent	0 (0.0)		
Implant shape			
Cylindrical	6 (4.8)	1.39 (0.46, 4.20)	0.767
Tapered	6 (3.5)		
Implant height (mm)			
<11	6 (3.2)	1.62 (0.54, 4.91)	0.546
≥11	6 (5.3)		
Implant diameter (mm)			
<4.5	9 (5.5)	0.41 (0.11, 1.49)	0.237
≥4.5	3 (2.2)		
Implant location			
Anterior maxilla	1 (3.1)	NA	0.070
Posterior maxilla	3 (2.8)		
Anterior mandible	0 (0.0)		
Posterior mandible	8 (5.3)		
Implant placement protocol			
Type I	0 (0.0)	NA	0.906
Type II	0 (0.0)		
Type III	1 (4.3)		
Type IV	11 (4.4)		
Bone augmentation procedure at the time of implant placement			
Yes	2 (3.3)	1.27 (0.29, 5.65)	0.75
No	10 (4.2)		
Operator			
Periodontist	5 (2.6)	2.43 (0.79, 7.48)	0.131
Oral and maxillofacial surgeon	7 (6.4)		
Prosthesis-related outcomes	<i>N</i> (%) diagnosed peri-implant mucositis	Relative risk (95% CI)	<i>p</i> value*
Type of prosthesis			
Single implant crown	9 (3.8)	0.79 (0.22, 2.85)	1.000
Multiple-unit implant-supported prosthesis	3 (4.8)		
Superstructure retention			
Screw-retained	5 (4.5)	1.15 (0.37, 3.53)	1.000
Cement-retained	7 (3.9)		
Number of functional years prior to diagnosis			
<5 years	8 (5.8)	2.39 (0.74, 7.78)	0.150
≥5 years	4 (2.4)		
Prosthetic complications			
Screw loosening			
Yes	1 (3.7)	1.08 (0.15, 8.08)	1.000
No	11 (4.0)		
Prosthetic complications			
Crown chipping			
Yes	1 (6.7)	1.79 (0.22, 14.82)	1.000
No	11 (3.8)		
Prosthetic complications			
Crown debonding			
Yes	2 (4.3)	1.08 (0.23, 5.12)	1.000
No	10 (3.9)		

CI: confidence interval. *Exact chi-square test.

accordance with the findings of other studies [13, 23, 27, 28]. In one study of 212 participants [27], the prevalence of peri-implantitis amongst patients without supportive peri-implant care was 43.9% compared to 18.0% in those that followed regular peri-implant maintenance.

History of treated periodontitis was another significant factor associated with peri-implantitis in the present study. Patients with a history of treated periodontitis were found to be at a seven times higher risk of peri-implantitis than periodontally healthy patients. Similar findings were

TABLE 5: Results of logistic regression analysis.

Predictor variable	Peri-implantitis		
	B Coefficient (SE)	p Value	Odds ratio (95% CI)
Smoking habits (yes = 0, no = 1)	2.15	0.008	8.55 (1.75, 42.10)
History of treated periodontitis (yes = 0, no = 1)	1.98	0.014	7.26 (1.48, 35.52)
Lack of regular peri-implant maintenance (yes = 0, no = 1)	2.34	0.036	10.41 (1.15, 93.69)

Model Chi-square = 22.88; *df* = 3; *p* < 0.0001. CI: confidence interval.

reported in several long-term studies [26, 28–37]. With over a 10-year follow-up period, Karoussis and co-workers [38] showed that the prevalence of peri-implantitis for periodontally compromised and healthy patients were 28.6% and 5.8%, respectively. A systematic review of 24 longitudinal studies highlighted the high risk for peri-implantitis in patients with treated periodontal diseases [39]. Besides the history of treated periodontitis, recurrent periodontal disease with residual probing depths of six or more millimeters during follow-ups has shown to have a significant impact on the incidence of peri-implantitis [40]. In another study of 70 periodontally-treated patients with 165 dental implants who were followed up for 3 to 23 years, the risk for developing peri-implantitis was significantly high in patients with a history of periodontitis and residual probing depths of ≥ 5 mm [28].

The third risk factor found to be significant in this study was smoking with smokers having eight times higher risk for peri-implantitis than non-smokers. This was in accordance with several studies and systematic reviews [13, 15, 23, 41, 42]. In one systematic review [13], smokers had a prevalence of peri-implantitis of 36.3%. Another systematic review and meta-analysis of 19,836 implants showed a higher incidence of postoperative infections and implant failure amongst smokers compared with non-smokers [42]. Smokers were also repeatedly reported to have a significant increase in peri-implant bone loss over time [43–45]. In addition to signs of inflammation, progressive bone loss beyond the bone level changes of initial remodeling was another observation that accompanied the diagnosis of peri-implantitis.

4.2. Implant-And Site-Related Risk Factors. An association between implant surface characteristics and risk for peri-implant diseases could not be detected since the implants used in this study were roughened-surface implants. Significant peri-implant marginal bone loss was observed around plasma-sprayed titanium implants compared to minimally roughened implants [46]. However; other studies [17, 23, 47] failed to demonstrate implant system characteristics as an independent risk factor for peri-implantitis.

The present study showed that implant placement protocol and use of grafting materials did not have any significant influence on the prevalence of peri-implant diseases. In contrast, a retrospective analysis of 188 patients with 423 implant-supported restorations showed that immediate implant placement and use of grafting material were significantly associated with peri-implant mucositis but were not identified as risk factors for peri-implantitis [23]. Interestingly, a retrospective study with a large sample size of 1017 patients and 3082 implant-supported restorations

showed that the use of non-autogenous bone grafting material with immediate implant placement increased the risk of early inflammation [48]. The lack of correlation between implant placement protocol or use of grafting materials and risk for peri-implant diseases; however, it does not necessarily exclude these variables as potential risk factors for early inflammation and peri-implant disease. In the present study, the limited number of immediately placed implants or cases where bone grafting was used may not have allowed proper assessment of these variables as risk factors.

4.3. Prosthesis-Related Risk Factors. There was no significant association between any of the prosthesis-related factors evaluated in this study and an increase in the risk for peri-implant diseases. This does not preclude that some prosthesis-related factors could be identified as potential risk factors. For example, cement-retained implant restorations were often accompanied by signs of peri-implant inflammation. Complete removal of subgingival excess cement may not be possible with a subsequent predisposition to peri-implant marginal bone loss and peri-implantitis [49]. A retrospective study of 249 implants has shown that cement-retained implant restorations had a 4.6 times higher risk of gingival inflammation compared to screw-retained implant restorations [50]. However, a statistically significant difference between cement- and screw-retained restorations was not found in terms of implant survival despite reporting more incidents of biological complications around cement-retained restorations [51, 52].

In the present study, a higher prevalence of peri-implantitis was reported around cement-retained implant restorations compared to screw-retained ones but the difference was not statistically significant. Placement of restoration margins closer to the most coronal mucosal levels might have allowed early detection and ease of removal of excess cement. Nevertheless, this cannot be confirmed as none of the participants were recalled to clinically assess the position of the restoration margins.

Several limitations can be identified in the present study. The retrospective design of the study with the inherent difficulty in collecting data or controlling all confounding factors is common. In addition, some outcomes were reported by a small number of cases and this might have underpowered the study. The use of implants from three systems could limit the extrapolation of the present study findings. Nevertheless, all included implants were placed in a standard clinical setting using a standardized surgical approach which might have reduced the impact of other confounding factors. In addition, the present study reported a nine-year follow-up where all the implants were placed in 2010, and data was collected up to 2019.

5. Conclusions

Within the limitations of this study, smoking habits, history of treated periodontitis and lack of peri-implant maintenance were significant risk factors for peri-implantitis. Early detection of these factors would ensure appropriate planning and care of patients at high risk of developing peri-implant diseases. Further studies with larger sample sizes are still required particularly in relation to the outcomes where data was not sufficient.

Data Availability

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical approval.

Additional Points

Clinical Relevance. *Scientific Rationale for the Study.* There is an indication that the prevalence of peri-implant diseases has increased over the last two decades. However, there is still a lack of literature on risk factors for peri-implant diseases in specific populations. *Principal Findings.* Smokers, those with a history of treated periodontitis, and patients who did not attend regular peri-implant maintenance visits were at high risk of developing peri-implantitis. *Practical Implications.* Early detection of smoking habits, history of treated periodontitis and lack of peri-implant maintenance may help clinicians in developing individualized preventive management strategies to maintain the longevity of dental implants.

Conflicts of Interest

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

Authors' Contributions

Momen A. Atieh designed the concept, analyzed and interpreted data, drafted article, critically revised the article, and approved the article. Zainab Almutairi collected the data, interpreted the data, critically revised the article, and approved the article. Fatemeh Amir-Rad critically revised the article and approved the article. Mohammed Koleilat critically revised the article and approved the article. Andrew Tawse-Smith critically revised the article and approved the article. Sunyoung Ma critically revised the article and approved the article. Lifeng Lin analyzed the data and approved the article. Nabeel H. M. Alsabeeha drafted the article, critically revised of article, and approved the article.

References

- [1] B. E. Pjetursson, D. Thoma, R. Jung, M. Zwahlen, and A. Zembic, "A systematic review of the survival and complication rates of implant-supported fixed dental prostheses (FDPs) after a mean observation period of at least 5 years," *Clinical Oral Implants Research*, vol. 23, no. Suppl 6, pp. 22–38, 2012.
- [2] M. A. Atieh, F. AlAli, and N. H. M. Alsabeeha, "Outcome of supportive peri-implant therapy on the rates of peri-implant diseases and marginal bone loss: a systematic review and meta-analysis," *Quintessence International*, vol. 52, no. 2, pp. 122–131, 2021.
- [3] Z. Berryman, L. Bridger, H. M. Hussaini, A. M. Rich, M. Atieh, and A. Tawse-Smith, "Titanium particles: an emerging risk factor for peri-implant bone loss," *The Saudi Dental Journal*, vol. 32, no. 6, pp. 283–292, 2020.
- [4] A. Tawse-Smith, M. A. Atieh, J. Leichter, L. Girvan, and A. M. Rich, "Peri-implant bone loss and its uncommon causes: a case report," *Clinical Advances in Periodontics*, vol. 5, no. 4, pp. 242–247, 2015.
- [5] M. A. Atieh, M. Shah, and N. H. Alsabeeha, "Etiology of peri-implantitis," *Current Oral Health Reports*, vol. 7, pp. 313–320, 2020.
- [6] T. Albrektsson and F. Isidor, "Consensus report of session IV," in *Proceedings of the 1st European Workshop on Periodontology*, pp. 365–369, Quintessence, Berlin, 1994.
- [7] S. Renvert, G. R. Persson, F. Q. Piri, and P. M. Camargo, "Peri-implant health, peri-implant mucositis, and peri-implantitis: case definitions and diagnostic considerations," *Journal of Periodontology*, vol. 89, no. Suppl 1, pp. S304–S312, 2018.
- [8] M. Sanz and I. L. Chapple, "Clinical research on peri-implant diseases: consensus report of working group 4," *Journal of Clinical Periodontology*, vol. 39, no. Suppl 12, pp. 202–206, 2012.
- [9] N. U. Zitzmann and T. Berglundh, "Definition and prevalence of peri-implant diseases," *Journal of Clinical Periodontology*, vol. 35, pp. 286–291, 2008.
- [10] O. C. Koldstad, A. A. Scheie, and A. M. Aass, "Prevalence of peri-implantitis related to severity of the disease with different degrees of bone loss," *Journal of Periodontology*, vol. 81, no. 2, pp. 231–238, 2010.
- [11] A. Mombelli, N. Muller, and N. Cionca, "The epidemiology of peri-implantitis," *Clinical Oral Implants Research*, vol. 23, no. Suppl 6, pp. 67–76, 2012.
- [12] C. T. Lee, Y. W. Huang, L. Zhu, and R. Weltman, "Prevalences of peri-implantitis and peri-implant mucositis: systematic review and meta-analysis," *Journal of Dentistry*, vol. 62, pp. 1–12, 2017.
- [13] M. A. Atieh, N. H. M. Alsabeeha, C. M. Faggion, and W. J. Duncan, "The frequency of peri-implant diseases: a systematic review and meta-analysis," *Journal of Periodontology*, vol. 84, no. 11, pp. 1586–1598, 2013.
- [14] J. Lindhe and J. Meyle, "Peri-implant diseases: consensus report of the sixth European workshop on periodontology," *Journal of Clinical Periodontology*, vol. 35, pp. 282–285, 2008.
- [15] L. J. A. Heitz-Mayfield, "Peri-implant diseases: diagnosis and risk indicators," *Journal of Clinical Periodontology*, vol. 35, pp. 292–304, 2008.
- [16] S. Rinke, S. Ohl, D. Ziebolz, K. Lange, and P. Eickholz, "Prevalence of periimplant disease in partially edentulous patients: a practice-based cross-sectional study," *Clinical Oral Implants Research*, vol. 22, no. 8, pp. 826–833, 2011.
- [17] S. Renvert, I. Polyzois, and N. Claffey, "How do implant surface characteristics influence peri-implant disease?" *Journal of Clinical Periodontology*, vol. 38, no. Suppl 11, pp. 214–222, 2011.
- [18] J. P. Vandenbroucke, E. von Elm, D. G. Altman et al., "Strengthening the reporting of observational studies in

- epidemiology (STROBE): explanation and elaboration," *Epidemiology*, vol. 18, no. 6, pp. 805–835, 2007.
- [19] C. H. F. Hämmerle, S. T. Chen, and T. G. Wilson, "Consensus statements and recommended clinical procedures regarding the placement of implants in extraction sockets," *The International Journal of Oral and Maxillofacial Implants*, vol. 19, no. Suppl, pp. 26–28, 2004.
- [20] M. G. Araujo and J. Lindhe, "Peri-implant health," *Journal of Periodontology*, vol. 89, no. Suppl 1, pp. S249–S256, 2018.
- [21] J. R. Landis and G. G. Koch, "The measurement of observer agreement for categorical data," *Biometrics*, vol. 33, no. 1, pp. 159–174, 1977.
- [22] I. Herrmann, U. Lekholm, S. Holm, and S. Karlsson, "Impact of implant interdependency when evaluating success rates: a statistical analysis of multicenter results," *The International Journal of Prosthodontics*, vol. 12, no. 2, pp. 160–166, 1999.
- [23] M. A. Atieh, J. K. Pang, K. Lian et al., "Predicting peri-implant disease: chi-square automatic interaction detection (CHAID) decision tree analysis of risk indicators," *Journal of Periodontology*, vol. 90, no. 8, pp. 834–846, 2019.
- [24] D. M. Daubert, B. F. Weinstein, S. Bordin, B. G. Leroux, and T. F. Flemmig, "Prevalence and predictive factors for peri-implant disease and implant failure: a cross-sectional analysis," *Journal of Periodontology*, vol. 86, no. 3, pp. 337–347, 2015.
- [25] D. French, H. M. Grandin, and R. Ofec, "Retrospective cohort study of 4, 591 dental implants: analysis of risk indicators for bone loss and prevalence of peri-implant mucositis and peri-implantitis," *Journal of Periodontology*, vol. 90, no. 7, pp. 691–700, 2019.
- [26] A. M. Roos-Jansaker, C. Lindahl, H. Renvert, and S. Renvert, "Nine- to fourteen-year follow-up of implant treatment. Part II: presence of peri-implant lesions," *Journal of Clinical Periodontology*, vol. 33, no. 4, pp. 290–295, 2006.
- [27] F. O. Costa, S. Takenaka-Martinez, L. O. M. Cota, S. D. Ferreira, G. L. M. Silva, and J. E. Costa, "Peri-implant disease in subjects with and without preventive maintenance: a 5 year follow-up," *Journal of Clinical Periodontology*, vol. 39, no. 2, pp. 173–181, 2012.
- [28] B. E. Pjetursson, C. Helbling, H. P. Weber et al., "Peri-implantitis susceptibility as it relates to periodontal therapy and supportive care," *Clinical Oral Implants Research*, vol. 23, no. 7, pp. 888–894, 2012.
- [29] P. Simonis, T. Dufour, and H. Tenenbaum, "Long-term implant survival and success: a 10–16 year follow-up of non-submerged dental implants," *Clinical Oral Implants Research*, vol. 21, no. 7, pp. 772–777, 2010.
- [30] I. K. Karoussis, S. Kotsovilis, and I. Fourmoussis, "A comprehensive and critical review of dental implant prognosis in periodontally compromised partially edentulous patients," *Clinical Oral Implants Research*, vol. 18, no. 6, pp. 669–679, 2007.
- [31] M. Quirynen, M. Abarca, N. Van Assche, M. Nevins, and D. van Steenberghe, "Impact of supportive periodontal therapy and implant surface roughness on implant outcome in patients with a history of periodontitis," *Journal of Clinical Periodontology*, vol. 34, no. 9, pp. 805–815, 2007.
- [32] C. T. T. Ong, S. Ivanovski, I. G. Needleman et al., "Systematic review of implant outcomes in treated periodontitis subjects," *Journal of Clinical Periodontology*, vol. 35, no. 5, pp. 438–462, 2008.
- [33] S. Renvert, C. Lindahl, and G. Rutger Persson, "The incidence of peri-implantitis for two different implant systems over a period of thirteen years," *Journal of Clinical Periodontology*, vol. 39, no. 12, pp. 1191–1197, 2012.
- [34] M. Rocuzzo, F. Bonino, M. Aglietta, and P. Dalmasso, "Ten year results of a three arms prospective cohort study on implants in periodontally compromised patients. Part 2: clinical results," *Clinical Oral Implants Research*, vol. 23, no. 4, pp. 389–395, 2012.
- [35] H. R. Dalago, G. Schuldt Filho, M. A. P. Rodrigues, S. Renvert, and M. A. Bianchini, "Risk indicators for Peri-implantitis. A cross-sectional study with 916 implants," *Clinical Oral Implants Research*, vol. 28, no. 2, pp. 144–150, 2017.
- [36] A. Monje, H. L. Wang, and J. Nart, "Association of preventive maintenance therapy compliance and peri-implant diseases: a cross-sectional study," *Journal of Periodontology*, vol. 88, no. 10, pp. 1030–1041, 2017.
- [37] F. Schwarz, J. Derks, A. Monje, and H. L. Wang, "Peri-implantitis," *Journal of Periodontology*, vol. 89, no. Suppl 1, pp. S267–S290, 2018.
- [38] I. K. Karoussis, G. E. Salvi, L. J. Heitz-Mayfield, U. Bragger, C. H. Hammerle, and N. P. Lang, "Long-term implant prognosis in patients with and without a history of chronic periodontitis: a 10 year prospective cohort study of the ITI Dental Implant System," *Clinical Oral Implants Research*, vol. 14, no. 3, pp. 329–339, 2003.
- [39] V. Sousa, N. Mardas, B. Farias et al., "A systematic review of implant outcomes in treated periodontitis patients," *Clinical Oral Implants Research*, vol. 27, no. 7, pp. 787–844, 2016.
- [40] J. Cho-Yan Lee, N. Mattheos, K. C. Nixon, and S. Ivanovski, "Residual periodontal pockets are a risk indicator for peri-implantitis in patients treated for periodontitis," *Clinical Oral Implants Research*, vol. 23, no. 3, pp. 325–333, 2012.
- [41] A. Turri, P. H. Rossetti, L. Canullo, M. G. Grusovin, and C. Dahlin, "Prevalence of peri-implantitis in medically compromised patients and smokers: a systematic review," *The International Journal of Oral and Maxillofacial Implants*, vol. 31, no. 1, pp. 111–118, 2016.
- [42] B. R. Chrcanovic, T. Albrektsson, and A. Wennerberg, "Smoking and dental implants: a systematic review and meta-analysis," *Journal of Dentistry*, vol. 43, no. 5, pp. 487–498, 2015.
- [43] M. Aglietta, V. I. Siciliano, G. Rasperini, C. Cafero, N. P. Lang, and G. E. Salvi, "A 10 year retrospective analysis of marginal bone-level changes around implants in periodontally healthy and periodontally compromised tobacco smokers," *Clinical Oral Implants Research*, vol. 22, no. 1, pp. 47–53, 2011.
- [44] M. De la Rosa, A. Rodriguez, K. Sierra, G. Mendoza, and L. Chambrone, "Predictors of peri-implant bone loss during long-term maintenance of patients treated with 10-mm implants and single crown restorations," *The International Journal of Oral and Maxillofacial Implants*, vol. 28, no. 3, pp. 798–802, 2013.
- [45] L. Levin, R. Hertzberg, S. Har-Nes, and D. Schwartz-Arad, "Long-term marginal bone loss around single dental implants affected by current and past smoking habits," *Implant Dentistry*, vol. 17, no. 4, pp. 422–429, 2008.
- [46] W. Becker, B. E. Becker, A. Ricci et al., "A prospective multicenter clinical trial comparing one- and two-stage titanium screw-shaped fixtures with one-stage plasma-sprayed solid-screw fixtures," *Clinical Implant Dentistry and Related Research*, vol. 2, no. 3, pp. 159–165, 2000.
- [47] L. Zetterqvist, S. Feldman, B. Rotter et al., "A prospective, multicenter, randomized-controlled 5 year study of hybrid and fully etched implants for the incidence of peri-

- implantitis,” *Journal of Periodontology*, vol. 81, no. 4, pp. 493–501, 2010.
- [48] T. Jemt, M. Karouni, J. Abitbol, O. Zouiten, and H. Antoun, “A retrospective study on 1592 consecutively performed operations in one private referral clinic. Part II: peri-implantitis and implant failures,” *Clinical Implant Dentistry and Related Research*, vol. 19, no. 3, pp. 413–422, 2017.
- [49] S. Renvert and M. Quirynen, “Risk indicators for peri-implantitis. A narrative review,” *Clinical Oral Implants Research*, vol. 26, no. Suppl 11, pp. 15–44, 2015.
- [50] P. Papaspyridakos, T. B. Bordin, Z. S. Natto et al., “Double full-arch fixed implant-supported prostheses: outcomes and complications after a mean follow-up of 5 years,” *Journal of Prosthodontics*, vol. 28, no. 4, pp. 387–397, 2019.
- [51] S. Sherif, H. K. Susarla, T. Kapos, D. Munoz, B. M. Chang, and R. F. Wright, “A systematic review of screw- versus cement-retained implant-supported fixed restorations,” *Journal of Prosthodontics*, vol. 23, pp. 1–9, 2014.
- [52] J. G. Wittneben, C. Millen, and U. Bragger, “Clinical performance of screw- versus cement-retained fixed implant-supported reconstructions--a systematic review,” *The International Journal of Oral and Maxillofacial Implants*, vol. 29, no. Supplement, pp. 84–98, 2014.