Review

The Frequency of Peri-Implant Diseases: A Systematic Review and Meta-Analysis

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Background: The peri-implant diseases, namely peri-implant mucositis and peri-implantitis, have been extensively studied. However, little is known about the true magnitude of the problem, owing mainly to the lack of consistent and definite diagnostic criteria used to describe the condition. The objective of the present review is to systematically estimate the overall frequency of peri-implant diseases in general and high-risk patients.

Methods: The systematic review is prepared according to the Meta-analysis of Observational Studies in Epidemiology statement. Studies were searched in four electronic databases, complemented by manual searching. The quality of the studies was assessed according to Strengthening the Reporting of Observational Studies in Epidemiology, and the data were analyzed using statistical software.

Results: Of 504 studies identified, nine studies with 1,497 participants and 6,283 implants were included. The summary estimates for the frequency of peri-implant mucositis were 63.4% of participants and 30.7% of implants, and those of peri-implantitis were 18.8% of participants and 9.6% of implants. A higher frequency of occurrence of peri-implant diseases was recorded for smokers, with a summary estimate of 36.3%. Supportive periodontal therapy seemed to reduce the rate of occurrence of peri-implant diseases.

Conclusions: Peri-implant diseases are not uncommon following implant therapy. Long-term maintenance care for high-risk groups is essential to reduce the risk of peri-implantitis. Informed consent for patients receiving implant treatment must include the need for such maintenance therapy. *J Periodontol 2013;84:1586-1598.*

KEY WORDS

Dental implants; diagnosis; epidemiology; meta-analysis; peri-implantitis; review.

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The use of oral implants to support fixed and removable prostheses is a widely accepted treatment modality of high success and predictability.[1-3] Despite the high success and survival rates of oral implants, failures do occur, and implant-supported prostheses may require substantial periodontal and prosthodontic maintenance over time.[4-6] Implant failures have been traditionally described as early or late. Early failures occur before implant loading and could be caused by surgery-, implant-, or host-related factors. Late failures, on the other hand, occur after prosthodontic rehabilitation as a result of peri-implant disease or biomechanical overload.[7,8] Peri-implant disease is thought to result in bone loss around the implants and subsequent loss of osseointegration.[7,9] An accurate estimate of the true prevalence of peri-implant disease, however, remains controversial. The inconsistencies in defining and reporting its two common forms, peri-implant mucositis and peri-implantitis, are very apparent.[10]

The term peri-implantitis first appeared in the literature in 1987 in a study by Mombelli et al.[11] It was described as an infectious disease with many features common to periodontitis. Since then, a growing interest in defining peri-implant disease as a clinical entity and proposing a treatment approach for it has been

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observed. The multifaceted etiology and varied characteristics of the disease, however, resulted in lack of consensus in defining peri-implant disease from a clinical perspective. For example, two consensus reports[12,13] define peri-implant mucositis as an inflammatory response limited to the soft tissues surrounding a functioning oral implant, whereas peri-implantitis elicits an inflammatory response that involves loss of marginal bone around a functioning oral implant. These reports, however, failed to set rigid clinical parameters that could be used to diagnose the two conditions. Furthermore, the 3rd International Team for Implantology Consensus Conference[14] presented similar definitions, and additional diagnostic parameters were also suggested. Accordingly, the presence of plaque and suppuration, bleeding on probing (BOP), and probing depth (PD) >5 mm were required to define peri-implantitis. Analysis of peri-implant sulcular fluid was also included as a diagnostic aid for peri-implantitis, albeit without indicating a specific marker for it.

Other variations of the above diagnostic criteria for peri-implant diseases also exist in the literature. For example, peri-implant mucositis was diagnosed based on the presence of BOP/suppuration and PD >4 mm, whereas peri-implantitis required PD >5 mm and radiographic bone loss of >0.2 mm annually or progressive bone loss of >3 threads combined with signs of peri-implant mucositis.[15-17]

The prevalence of peri-implant diseases has been reported in the literature.[6,13,18] However, considerable variations among these studies are noted. In a systematic review by Berglundh et al.,[18] the biologic and technical complications in oral implant therapy were summarized by reviewing a large number of longitudinal prospective studies. Peri-implantitis, as defined by Albrektsson and Isidor,[12] was reported in 6.47% of the implants included in their review. In contrast, Zitzmann and Berglundh[13] showed that the frequency of peri-implantitis varied between 28% and ≥56% of the participants and 12% and 43% of individual implants. The causes for the discrepancy in the results reported in these systematic reviews could be the lack of standardized criteria for diagnosing peri-implant mucositis and peri-implantitis, the different implant systems used, or the differences in the observation periods.

The impact of peri-implant diseases on treatment outcomes with oral implants has gained much interest in recent years. It is deemed essential to determine the true prevalence of peri-implant disease to allow well-informed consent and develop rigid supportive maintenance programs for high-risk groups. The aim of this article, therefore, is to systematically review the current literature and perform a meta-analysis to estimate the prevalence of peri-implant disease and determine the risk factors associated with its development in patients receiving oral implant treatment.

MATERIALS AND METHODS

The current systematic review and meta-analysis conforms to the guidelines outlined by the Meta-analysis of Observational Studies in Epidemiology (MOOSE) statement.[19] The focused question formulated to summarize the objectives of the study was: What is the prevalence of peri-implant diseases in general and high-risk participants over 5 years? The presence of one or more of three risk factors (history of periodontal disease, smoking, and diabetes) is required to define a participant at high risk. An observation period of >5 years was selected because peri-implant mucositis and peri-implantitis are slowly progressing diseases that seem to require long-term follow-up to be identified.[20]

Inclusion Criteria

Studies were selected if they met the following inclusion criteria: 1) report written in English; 2) human study population; 3) prospective, retrospective, cross-sectional, and observational cohort study reporting the number of cases of peri-implant mucositis and/or peri-implantitis using specific clinical parameters; 4) follow-up duration of at least 5 years of functional loading time, an observation period needed to critically assess the prevalence of peri-implant diseases. In the case of multiple publications of the same study, the one with the most detailed information was included.

Exclusion Criteria

Studies were excluded if they: 1) were case series or case reports; 2) did not clearly define clinical parameters to define peri-implant diseases; 3) failed to report the number of implants with peri-implant diseases; or 4) had an observation period of <5 years after functional loading.

Search Strategy

The relevant articles were retrieved from the following electronic databases: 1) MEDLINE; 2) Embase; 3) Cochrane Central Register of Controlled Trials (Central); and 4) the MetaRegister for ongoing and unpublished trials. The search was performed up to January 30, 2012, and included the key words listed in Table 1. Two authors (MA and NA) performed the search independently, in duplicate, and any disagreement was solved by consensus. The bibliographies of potentially selected papers were scrutinized for additional

Table 1.

Search Strategy

Database	Key words
Published studies	
MEDLINE via Ovid (January 30, 2012)	(exp peri-implantitis/OR peri-implantitis.mp OR peri-implant mucositis.mp. OR peri-implant mucositis OR perimucositis) AND (exp Dental Implants/OR exp Dental Implantation OR ((dental or oral) adj5 implant$).mp.)
Embase via Ovid (January 30, 2012)	(exp peri-implantitis/ OR peri-implantitis.mp. OR peri-implant mucositis.mp. OR peri-implant mucositis OR perimucositis) AND (dental implantation.mp. OR ((dental or oral) adj5 implant$).mp.)
Cochrane Central Register of Controlled Trials (Central) via Ovid (January 30, 2012)	(peri-implantitis.mp. OR peri-implantitis.mp. OR peri-implant mucositis.mp. OR peri-implant mucositis.mp.) AND (exp Dental Implant/OR exp Dental Implantation/OR ((dental or oral) adj5 implant$).mp.)
Unpublished studies	
MetaRegister (January 31, 2012)	(peri-implantitis or periimplantitis), (peri-implant mucositis or perimucositis)

material. A manual search was also conducted within the last 10 years of the following journals: *Clinical Implant Dentistry and Related Research*, *Clinical Oral Implants Research*, *Implant Dentistry*, *International Journal of Oral & Maxillofacial Implants, International Journal of Periodontics and Restorative Dentistry*, *Journal of Clinical Periodontology*, *Journal of Dental Research*, *Journal of Oral Implantology*, and *Journal of Periodontology*.

Data Collection

Once a study was included in the analysis, two authors (MA and NA) independently used a predetermined data collection form to extract the following information: 1) title of the study; 2) year of publication; 3) country of origin; 4) number of participants/implants; 5) implant design and system; 5) number of participants/implants associated with peri-implant mucositis and/or peri-implantitis; and 6) associated risk factors (history of periodontal disease, smoking, and diabetes). Data related to the smokers or patients with periodontitis were separately reported from the studies that clearly defined the number of cases of peri-implant diseases in smokers or those who had periodontitis and/or diabetes. Any disagreements in the data collection reports were resolved by consensus. Attempts were made to contact the corresponding authors when additional information was needed.

Definition of Peri-Implant Diseases

The clinical criteria set to define peri-implant disease in this review are determined based on established consensus reports, workshop summaries, and reviews.[12-14,21] Peri-implant mucositis is defined as an inflamed mucosa with a bleeding index of ≥2 and/or suppuration but without bone loss. Peri-implant bleeding tendency is assessed using the modified sulcus bleeding index.[11] Peri-implantitis is defined as the presence of inflamed mucosa with a positive BOP, PD ≥5 mm, and cumulative bone loss of ≥2 mm and/or ≥3 threads of implant (Fig. 1). Studies not conforming to the specific clinical criteria defining peri-implant disease in this review are excluded from the analysis.

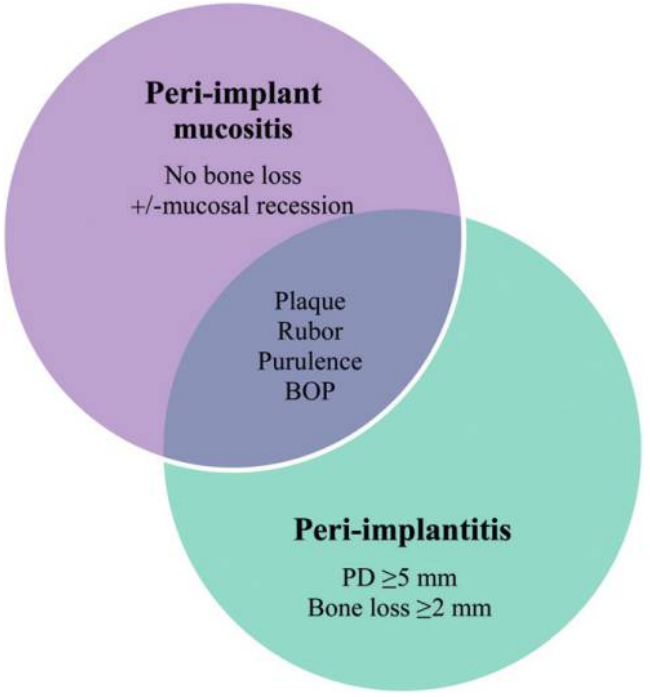

Figure 1.
Diagnostic criteria of peri-implant diseases.

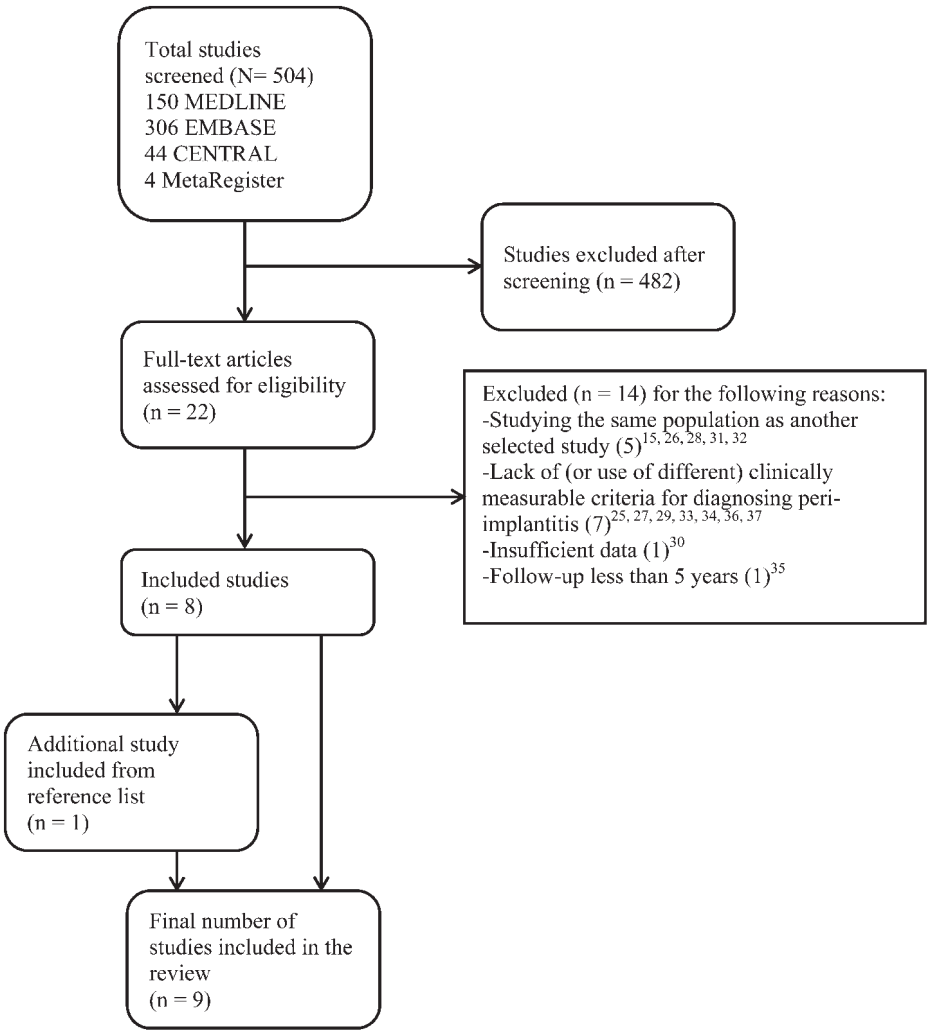

Figure 2.
Flowchart of the search process.

Quality Assessment and Data Synthesis

A quality assessment tool derived from the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement[22] was developed to assess the quality of reporting of the studies. A single point was given for each item in the study meeting the predefined criteria, for a total of 12 items. Therefore, a summary score between 0 and 12 was given for each study, with a higher score indicating better study quality. A statistical software program‡ was used to conduct the meta-analysis. The summary estimate of the frequency of peri-implant diseases was determined using a random-effect model[23] at both participant and implant levels depending on the selected unit of statistical analysis. Heterogeneity across the studies was assessed using the I^2 statistic.[24] An I^2 value >50 indicates significant heterogeneity.

Sensitivity and Subgroup Analyses

Sensitivity analysis was performed to evaluate the influence of deleting studies that may have influence on the meta-analytic summary estimate. Subgroup analysis was undertaken to provide a prevalence estimate of peri-implant diseases based on the presence of risk factors (smoking, diabetes, and history of periodontal disease), as well as the effect of a preventive maintenance program, where those data were separately reported in the selected studies.

RESULTS

A total of 504 studies were identified from the databases (Fig. 2). Only 22 studies were eligible for full-text evaluation. Of these, 14[15,25-37] were excluded and one was selected from a reference list, resulting in nine papers included in the meta-analysis.[16,38-45] The manual search did not provide any further studies.

Description of Studies

The characteristics of the nine studies are summarized in Table 2. A total of 6,283 implants and 1,497 participants were available at the end of the follow-up period. All the studies were conducted in a university setting except two,[38,44] where implant placement and maintenance were carried out in private dental practices. The observation period ranged from 5 years[39] to >10 years.[16,42,45] All of the studies presented data on the frequency of peri-implantitis, whereas only five studies provided information on the frequency of peri-implant mucositis.[16,39,41,43,44] Two studies used the participant as the statistical unit of analysis,[39,44] whereas in another two,[41,42] data analysis was based on the implant. The remaining five studies[16,38,40,43,45] presented their results at both participant and implant levels. Six studies[16,38,39,42-44] made provisions for a supportive maintenance program during the observation period. In two of

‡ STATA, v.10.1, Stata, College Station, TX.

Table 2.

Characteristics of the Included Studies

	Cho-Yan Lee et al.[38]	Ferreira et al.[39]	Fransson et al.[40]	Kaemmerer et al.[41]	Karoussis et al.[42]	Koldsland et al.[43]	Rinke et al.[44]	Roos-Jansåker et al.[16]	Simonis et al.[45]
Study design	Retrospective	Cross-sectional	Cross-sectional	Retrospective	Prospective	Cross-sectional	Cross-sectional	Cross-sectional	Retrospective
Location	Australia	Brazil	Sweden	Germany	Switzerland	Norway	Germany	Sweden	France
Participants/implants (n)*	60/117	212/578	662/3,413	41/237	53/112	109/351	89/357	216/987	55/124
Supportive periodontal maintenance program	Provided	Provided	NR	NR	Provided	Provided	Provided	Provided	NR
Implant system	A†	B,‡ C,§D‖	B‡	E¶	A†	B,‡ C,§ E¶	F#	B‡	A†
Implant surface topography	Titanium plasma-sprayed and sand-blasted acid-etched solid screws, hollow screws, and hollow cylinders	Oxidized surface, dual acid-etched, and bioceramic microblasted surface	Oxidized surface	Moderately rough surface, grit-blasted with particles of titanium oxide	Plasma-sprayed	Oxidized surface, acid-etched and dual acid-etched	Microtextured surface	Oxidized surface	Titanium plasma-sprayed cylindric
Peri-implant mucositis (n)									
Participants	NR	137	NR	NR	NR	41	40	167	NR
Implants	NR	NR	NR	21	NR	82	NR	478	NR
Peri-implantitis (n)									
Participants	16	19	184	NR	NR	49	10	62	9
Implants	23	NR	423	5	13	108	NR	69	21
Mean follow-up period (years)	8	5	9.1	9.1	10	8.4	5.7	11.5	13
Modified STROBE rating	10	9	8	7	5	9	7	7	9

NR = not reported.
* Included in the analysis at the end of follow-up period.
† Straumann, Basel, Switzerland.
‡ Nobel Biocare, Göteborg, Sweden.
§ 3i Implant Innovations, Palm Beach Gardens, FL.
‖ Intra-lock International, Boca Raton, FL.
¶ Astra Tech, Mölndal, Sweden.
# DENTSPLY Friadent, Mannheim, Germany.

these studies,[16,43] the maintenance program was carried out by the referring dentist.

In a cohort study of 53 partially edentulous patients treated with implant-supported fixed prostheses, the authors assessed the technical and biologic complications over 10 years.[42] The terms *peri-implantitis* and *biologic complication* were used interchangeably by the authors and indicated the presence of PD ≥5 mm, bleeding/suppuration on probing, and radiographic bone loss. It was shown that participants with a previous history of periodontitis treated before implant placement were at a higher risk of developing peri-implantitis. In addition, smokers were also found to be at a higher risk compared with non-smokers, but the difference was not statistically significant.

Fransson et al.[40] examined the intraoral radiographs of 662 participants with 3,413 implants that were in function for 5 to 20 years. Peri-implantitis was defined as progressive bone loss of >3 threads. Results showed that 12.4% of implants and 27.8% of participants presented with signs of peri-implantitis. The use of participants rather than implants as the unit of analysis was emphasized, as the larger number of implants tends to dilute the prevalence rate.

Roos-Jansåker et al.[16] reported the prevalence of peri-implant disease in 218 patients with 999 implants after 9 to 14 years of function. The prevalence rate of peri-implant mucositis ranged from 18.3% to 76.6%, and that of peri-implantitis ranged from 3.7% to 28.7% depending on the PD measurements. A supportive maintenance program, although not standardized to all patients, was provided by the referring clinicians. It was concluded that without supportive maintenance therapy, peri-implant disease could be a common complication in the long term.

In a cross-sectional study, Ferreira et al.[39] investigated the prevalence of peri-implant mucositis and peri-implantitis in a population of 212 participants. All relevant clinical parameters were assessed by two investigators masked to the identity and medical background of the participants. A logistic regression analysis identified high plaque scores and poor glycemic control to be risk factors for the development of peri-implant disease. On the other hand, and contrary to other studies, the number of maintenance visits did not seem to prevent or reduce the incidence of peri-implant disease.

Koldsland et al.[43] reported the prevalence of peri-implant mucositis and peri-implantitis in a population of 109 participants followed for up to 10 years. The authors presented their findings at the participant and implant levels. The prevalence of peri-implantitis varied from 11.3% to 47.1% for participants depending on the severity of the disease, which was assessed according to the extent of PD (≥4 or ≥6 mm) and radiographic marginal bone loss (≥2 or ≥3 mm).

Simonis et al.[45] examined different variables related to implant success in 55 participants with 131 roughened-surface implants over a 7-year period. The prevalence of peri-implantitis was reported at both implant and participant levels. Results showed that 16.94% of the implants and 16.36% of the participants were affected by peri-implantitis. Years of functional loading and history of periodontitis were considered significant risk factors for developing peri-implantitis.

Cho-Yan Lee et al.[38] investigated the effect of periodontal condition of the host on prevalence of peri-implantitis. A total of 60 participants were selected from a pool of patients who received implant treatment in private practice. Participants with a history of periodontitis were divided into two groups: those with at least one periodontal PD ≥6 mm and those with no residual periodontal pockets at the follow-up visit. All participants were enrolled in a strict maintenance program throughout the observation period. The findings suggested that a history of periodontitis, per se, is not a risk factor for the development of peri-implantitis unless the periodontitis is recurrent with residual periodontal pockets of ≥6 mm at the follow-up examination. The authors recommended that for patients with a history of periodontitis, elimination of any residual periodontal pockets is essential.

Kaemmerer et al.[41] reported on the prevalence of peri-implant mucositis and peri-implantitis in 41 participants with 237 moderately roughened implants followed for 9 years. A correlation between the onset of peri-implant disease and implant loading time was not established. However, factors such as nicotine intake, alcohol abuse, and previous radiation therapy were found to significantly increase the risk of developing peri-implant disease.

In a recent retrospective cross-sectional study, Rinke et al.[44] described the prevalence of peri-implant diseases in 89 participants recruited from private dental practices. Based on participant-related analysis, the overall prevalence rates of peri-implant mucositis and peri-implantitis were 44.9% and 11.2%, respectively. In agreement with the findings of Karoussis et al.,[42] smokers had a 31-fold higher chance for the development of peri-implantitis than non-smokers. There was no attempt in this study to categorize smokers on the basis of packs/day; instead, the authors defined "smoker" as anyone who was smoking at the time of follow-up visit or had quit smoking for <5 years.

Table 3.

Summary of Modified STROBE Score

Item	Studies Reporting the Item (n)	References
Study design		
Study setting	9	16,38-45
Participant inclusion and exclusion criteria	6	38-41,43,44
Sample size and power calculation	1	38
Diagnostic criteria for defining peri-implant diseases	9	16,38-45
Masked assessment of outcomes	1	39
Statistical methods	9	16,38-45
Results		
Characteristics of participants	5	38-40,43,45
Reasons for non-participation	3	16,40,45
Outcome data reported at both patient and implant level	5	16,38,40,43,45
Data reported in participants with risk factors	7	38,39,41-45
Discussion		
Limitations	7	16,38,39,41,43-45
Interpretation	9	16,38-45

Regular attendance to a maintenance program was shown to reduce the prevalence of peri-implant disease. In addition, a history of periodontal disease showed a synergistic effect in increasing the prevalence of peri-implantitis in smokers.

Quality of Studies

The STROBE score ranged between 5 and 10 quality points (Table 3). All the included studies met the criteria related to describing the study setting, periods of recruitment, diagnostic clinical parameters, statistical methods, and the way the results were interpreted. Only one study[38] determined the sample size and conducted a power analysis calculation. Strategies to minimize potential sources of bias were not clearly described in any of the included studies, although in one article[39] the use of masked outcome assessors was reported.

Meta-Analysis

At the participant level, the computed overall summary estimates for the frequency of peri-implant mucositis and peri-implantitis were 63.4% (95% confidence interval [CI] 59.8% to 67.1%; P <0.001) (Fig. 3) and 18.8% (95% CI 16.8% to 20.8%; P <0.001) (Fig. 4), respectively. At the implant level, the summary estimates for the frequency of peri-implant mucositis and peri-implantitis were 30.7% (95% CI 28.6% to 32.8%; P <0.001) (Fig. 5) and 9.6% (95% CI 8.8% to 10.4%; P <0.001) (Fig. 6). A high heterogeneity was demonstrated among the study estimates (I^2 = 94.9% to 99.2%; P <0.001). Sensitivity analysis revealed that eliminating the Roos-Jansåker et al.[16] study from the meta-analysis resulted in significant changes in the summary estimates for the frequency of peri-implant mucositis, with 54.1% and 15.1% at the participant and implant levels, respectively. On the other hand, the elimination of each study in turn did not influence the summary estimates for the frequency of peri-implantitis. A funnel plot was not used to assess the publication bias because of the small number of included studies.[46]

Subgroup Analyses

The calculated summary estimate for the frequency of occurrence of peri-implantitis in participants with a history of periodontitis was 21.1% (95% CI 14.5% to 27.8%; P = 0.06) (Fig. 7). A moderate-to-low heterogeneity was demonstrated across the studies. In only two studies,[44,45] the frequency of peri-implantitis was separately reported in smokers, and its summary estimate was 36.3% (95% CI 18.4% to 54.2%; P = 0.18) (Fig. 8). For the participants who were enrolled in supportive maintenance programs, the overall estimated summary of the frequency of peri-implantitis was reduced to 14.3% (95% CI 11.8% to 16.9%; P <0.001) (Fig. 9).

DISCUSSION

This systematic review and meta-analysis aims to determine the prevalence of peri-implant disease and its associated risk factors in patients treated with oral implants. The guidelines of MOOSE[19] were followed. The participant-based analysis showed a high frequency of peri-implant diseases, with 63.4% for peri-implant mucositis and 18.8% for peri-implantitis. By pooling the extracted data with the implant as a unit of analysis, lower rates of 30.7% and 9.6% were estimated for peri-implant mucositis and peri-implantitis, respectively. A subgroup analysis assessing the frequency of peri-implantitis in high-risk group participants revealed a small increased frequency of peri-implantitis among the participants with a history of periodontal disease. However, the use of regular supportive periodontal care programs seemed to reduce the number of participants presenting with peri-implantitis. In addition, the frequency of the participants with

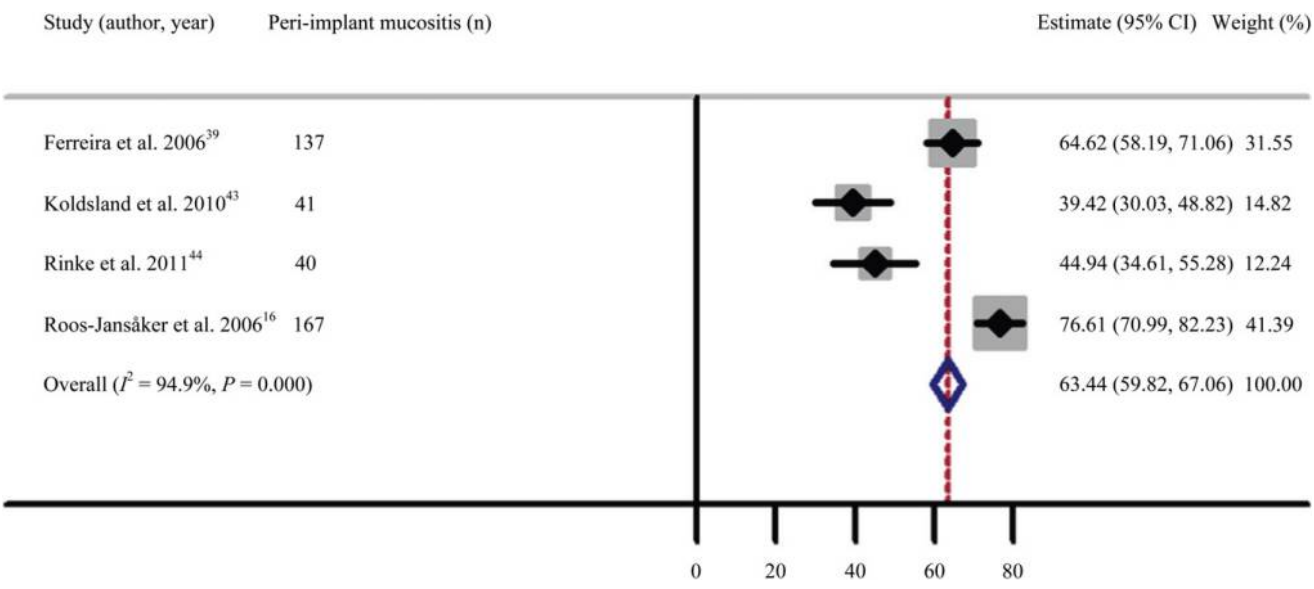

Figure 3.
Meta-analysis plot of the participant-based frequency estimate of peri-implant mucositis.

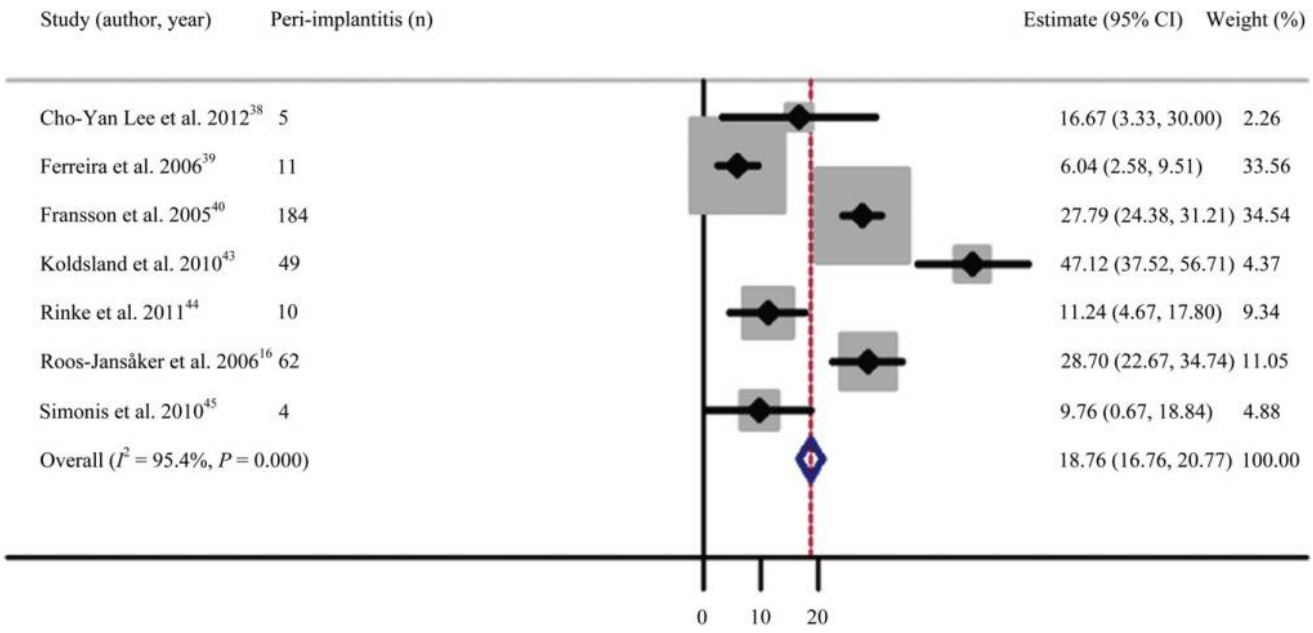

Figure 4.
Meta-analysis plot of the participant-based frequency estimate of peri-implantitis.

implants exhibiting peri-implantitis was significantly higher among smokers (36.3%), despite the limited number of studies reporting separate data for smokers.

The findings of the subgroup analysis were evaluated based on the guidelines suggested by Oxman and Guyatt.[47] The subgroup analysis was planned before conducting the search on the basis of the previously reported risk factors of peri-implant diseases and the influence of regular maintenance care. The difference in prevalence among the different subgroups was not significant, but inconsistency among the studies was noted. Therefore, the present conclusions from subgroup analysis, which included a subdivision of a small number of the included studies, should be interpreted cautiously.

The use of participants versus implants as the statistical unit of analysis remains an issue of

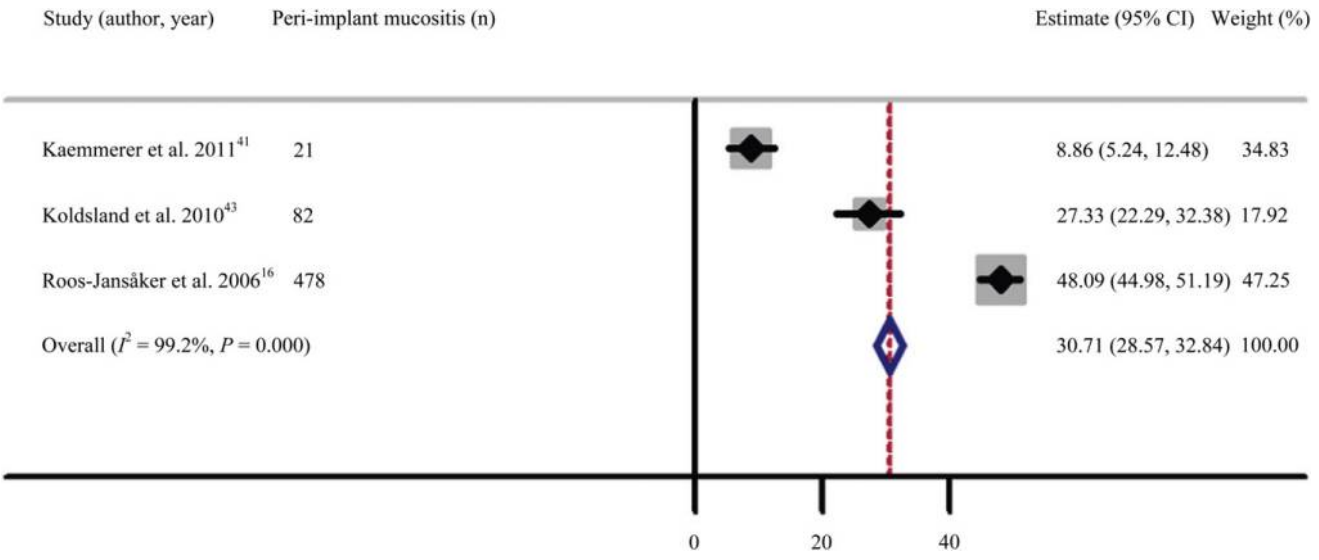

Figure 5.
Meta-analysis plot of the implant-based frequency estimate of peri-implant mucositis.

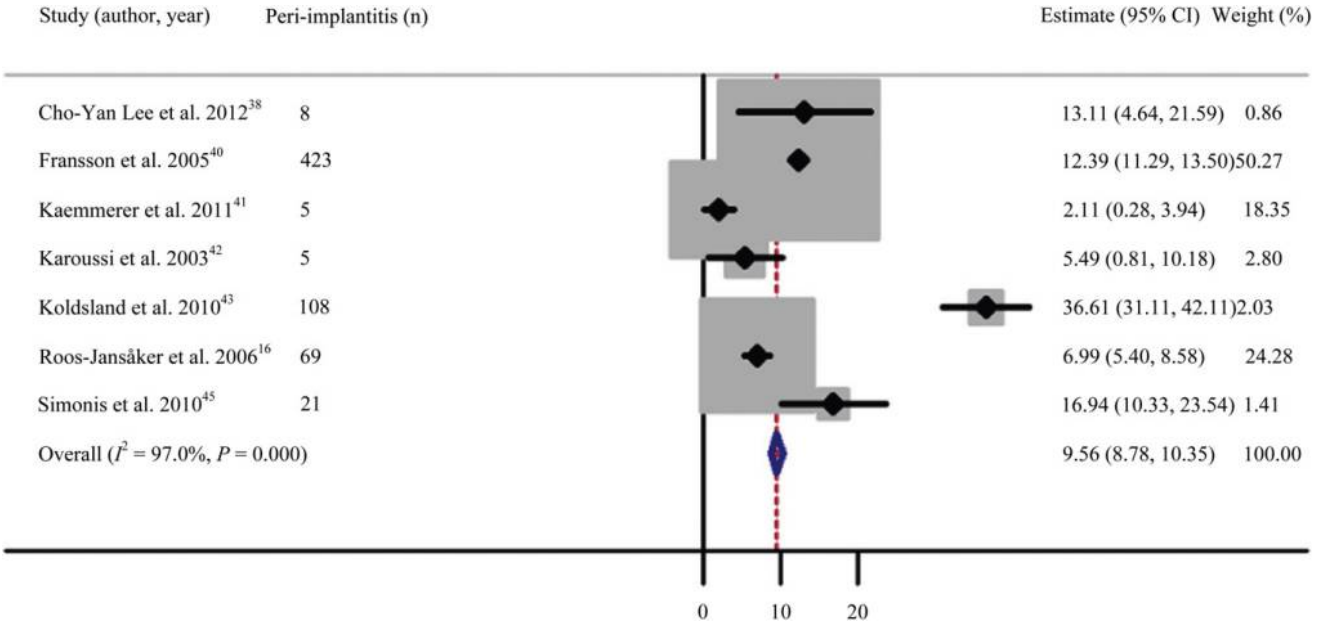

Figure 6.
Meta-analysis plot of the implant-based frequency estimate of peri-implantitis.

considerable impact limiting data comparisons among systematic reviews. It is the view of the authors that the choice of the unit of analysis should depend on the outcome evaluated. For example, when comparing treatment protocols or morphologic features of implant designs and surfaces, the implant could be used as the unit of analysis, whereas the participant would be a more appropriate unit of analysis in studies evaluating demographics, compliance issues, and systemic complications of implant therapy. It is apparent that in studying the frequency of peri-implant diseases, data based on implants rather than participants as the unit of analysis could underestimate the true prevalence of the condition.[40] This is because each implant is not an independent unit, and intraparticipant correlation among implants needs to be accounted for.[48] In addition, the use of an implant as a statistical unit may result in a statistically invalid estimation, particularly in high-risk groups where the difference

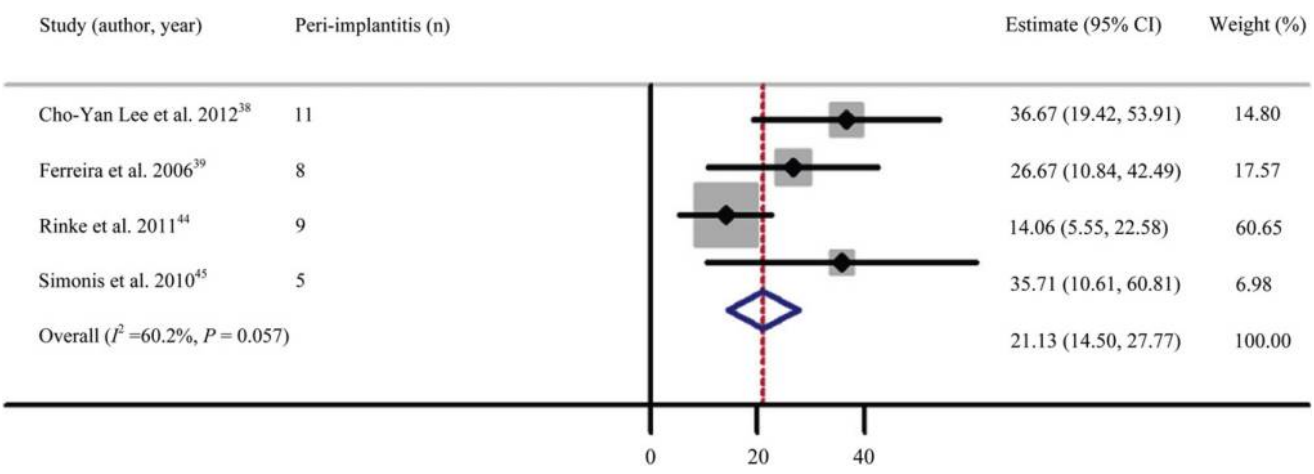

Figure 7.
Meta-analysis plot of the frequency estimate of peri-implantitis in participants with a history of periodontitis.

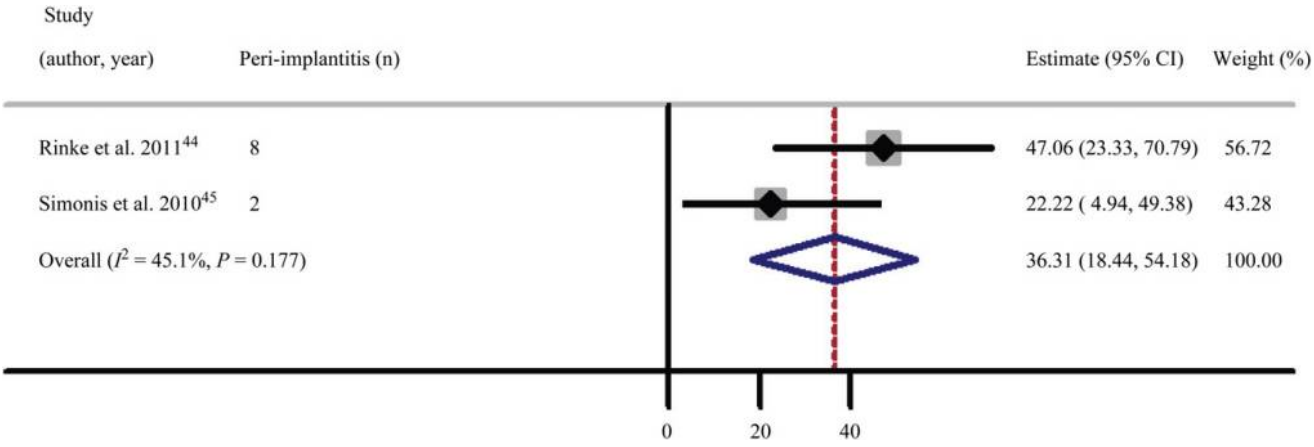

Figure 8.
Meta-analysis plot of the frequency estimate of peri-implantitis in smokers.

between an implant and a participant unit is more apparent.

Several systematic reviews have previously reported on the prevalence of peri-implant diseases.[6,13,18] In the review by Berglundh et al.,[18] only half of the included studies provided data on the presence of peri-implant diseases. The results showed a frequency value of 6.47% for peri-implantitis in partially edentulous patients with the implant as the unit of analysis. Pjetursson et al.[6] evaluated implant survival and technical and biologic complications of implant-supported fixed partial dentures over 5 and 10 years of function. A total of 21 studies were included in the analysis, which reported a frequency of occurrence of 8.6% for peri-implantitis. It was concluded that despite the high survival rates of implants over 5 years of service, considerable chair time was required for maintenance of the prostheses. In another review, Zitzmann and Berglundh[13] applied predefined clinical parameters to diagnose peri-implant diseases and excluded studies that had small sample size (<50) or <5 years' follow-up. Nine studies were identified,[16,38-45] but the prevalence of peri-implant mucositis was reported in just one study,[16] whereas that of peri-implantitis was reported in three population samples;[16,26,40] no meta-analysis was performed. The results were presented at both the participant and implant levels, with 80% of the participants and 50% of the implants exhibiting peri-implant mucositis. The rates of occurrence of peri-implantitis ranged between 28% and ≥56% of participants and 12% and 43% of implant sites.

The present systematic review attempts a more rigorous approach to substantiate its findings compared with the aforementioned reviews. Initially, an

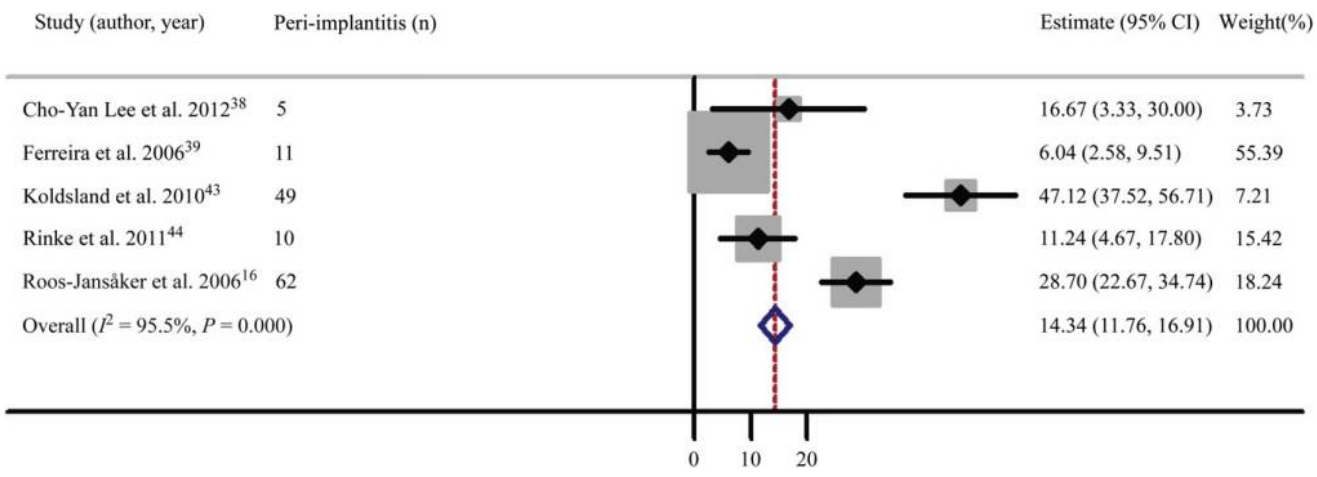

Figure 9.
Meta-analysis plot of the frequency estimate of peri-implantitis in participants who received supportive periodontal care.

extensive search strategy that included unpublished trials and manual searching of relevant journals was used. Further, known methodologic guidelines (i.e., MOOSE) meeting strict inclusion criteria and assessing the quality of the included studies were followed. In addition, standardized diagnostic criteria defining peri-implant disease were applied to all selected studies. This helped in minimizing heterogeneity among the studies and allowed the use of meta-analysis to calculate a summary estimate of the frequency of peri-implant diseases. On the other hand, the meta-analytic findings may need to be cautiously interpreted owing to the limited number of potentially relevant studies included in the analysis. Variation in study design, implant systems used, and duration of follow-up periods remains an inherent limitation that needs to be acknowledged, as does the lack of standardization in reporting outcomes at both participant and implant levels. Another limitation came from restricting the search to English, as relevant studies may have been published in other languages. The modified tool that assessed the quality of reporting of the studies, albeit not fully validated, was based on a validated assessment tool. The modified version was proposed due to the lack of a standardized assessment tool for evaluating the quality of non-randomized studies.

Sensitivity analysis is often performed to evaluate the robustness of the overall effect estimate by excluding a study that is considered an outlier and evaluating its influence on the overall outcome of the review.[49] In the present review, sensitivity analyses show that one study[16] may have overestimated the calculated frequency of peri-implant mucositis at both the participant and implant levels. The lack of standardized supportive maintenance care may have resulted in the reported high percentage of participants and implants with peri-implant diseases. The maintenance care was carried out by the referring dentists, and records have shown that participants attend visits only when prosthodontic maintenance is required.

Contrary to previous reports and reviews,[16,42,50] the present systematic review shows that history of periodontitis did not significantly increase the occurrence of peri-implantitis. However, the summary estimate of frequency of peri-implantitis among the participants that had regular maintenance procedures was considerably reduced. In one study,[44] the frequency of peri-implantitis among participants with a history of periodontal disease was comparable to that of those without a history of periodontal disease. The authors attributed the favorable results to the effect of regular maintenance and showed that the lack of such a supportive care program increased the risk of peri-implant disease by 11-fold. The importance of supportive periodontal maintenance care was further demonstrated in another review[51] that concluded that supportive periodontal therapy can maintain moderately rough implants in periodontally compromised patients.

Considering that >2 million oral implants are placed annually,[20] peri-implant disease can affect more than half a million implants each year. Therefore, clinicians and patients must be prepared to accept long-term, regular maintenance care to identify early signs of the disease and develop treatment strategies, particularly for those at high risk. Although the relationship between peri-implant mucositis and peri-implantitis is still not fully understood, regular follow-up care may also allow early intervention that may halt the potential progression of peri-implant mucositis into

peri-implantitis. The usefulness of meta-analysis is significantly enhanced as the number of studies suitable for inclusion increases; to this end, researchers and clinicians should be strongly encouraged to adhere to standardized guidelines for reporting observational and clinical data and use precise and clear diagnostic criteria that may allow a better understanding of the overall effect of peri-implant diseases.

CONCLUSIONS

Within the limitations of this systematic review and meta-analysis, there is a relatively high occurrence of peri-implant diseases that can manifest and persist for years. Long-term maintenance care for high-risk groups is essential to reduce the risk of peri-implantitis. Informed consent for patients receiving implant treatment must include the need for such maintenance therapy.

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