Peri-implantitis Risk Assessment (PiRA)

Part 1: Umbrella review of a Multifactorial Disease

With Many Risk Factors

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Abstract

Aim: An objective pre-operative assessment of patients' susceptibility to peri-implantitis could reduce the incidence of the disease and may be helpful in convincing patients to change their lifestyle, thereby reducing risk factors, or to forgo implant therapy in high-risk conditions. Material & methods: An umbrella review was performed to identify patient-related risk factors, together with their relative impact (odds ratio/relative risk). Potential treatment-related confounders for the development of peri-implantitis were also searched for. Results: Ten relevant patient-related risk factors for peri-implantitis were identified. While some of them are modifiable (smoking, bleeding on probing, plaque control, number of sites with PPD ≥ 5 mm, recall frequency, occlusal overload), others are not (history of periodontitis, implant location, number of teeth lost, systemic diseases). The relative impact of these factors differed largely between systematic reviews, most of which unfortunately limited their analysis to one or only a few factors, without taking other factors into

consideration, with the potential risk of misinterpretation/overrating. Moreover, patients' susceptibility might change due to a number of confounders (iatrogenic factors, surgical protocol, implant and implant site characteristics, etc.), and these factors should also be considered. Conclusions: The number of risk factors and potential confounders underline the complexity and multi-factorial etiology of peri-implantitis. *Int J Oral Maxillofac Implants 2025;40:xxx–xxx. doi: 10.11607/jomi.11107*

Key words: abutment material, biofilm, bleeding on probing, bruxism, cement remnants, etiology, full edentulism, GBR, genotype, implant insertion timing, keratinized tissue, microbiology, multi-causality, oral hygiene, partial edentulism, periodontitis, peri-implantitis, peri-implantitis confounding factors, recall compliance, smoking, supportive periodontal therapy, implant surface roughness.

CLINICAL RELEVANCE

SCIENTIFIC RATIONALE FOR STUDY. This umbrella review investigated risk factors, supported by at least one systematic review, for the development of peri-implantitis. It aimed to assess their relative importance.

PRINCIPAL FINDINGS. Ten relevant patient-related risk factors were identified. The modifiable ones were smoking, bleeding on probing, plaque control, number of sites with PPD ≥ 5 mm, recall frequency, occlusal overload. Their relative importance is unclear, as most studies did not control for more than one risk factor.

PRACTICAL IMPLICATIONS. Clinicians can use these findings to better understand the risk posed by different factors for the development of peri-implantitis.

Introduction

The patient-level prevalence of peri-implantitis is around 22%.[1] This is rather alarming, as implant therapy is becoming increasingly popular, and the treatment of peri-implantitis is complex and not always predictable.

The etiology of peri-implantitis is multifactorial and some individuals seem to be more prone to its development than others. Such patients often present one or more risk factors. For peri-implantitis, general risk factors are related to the individual (e.g. genetic predisposition), while local factors also play a significant role. Furthermore, several iatrogenic risk factors have been identified[2–4] and there are some indications that the risk for peri-implantitis is higher for implants placed in the mandible, when compared to the maxilla.[5]

Since the outcome of peri-implantitis treatment is not always predictable,[6] focus should be on disease prevention. Given that host factors are a major determinant of disease onset and progression, and that risk and susceptibility vary greatly between individuals, a tool that enables better patient selection by accurately identifying relevant risk factors may reduce patients' susceptibility to peri-implantitis.

This umbrella review aimed to identify relevant pre-operative risk factors for peri-implantitis and provide an overview of their relative impact. Based on this information and a retrospective study, a risk calculator (PiRA) was developed. Since some factors are modifiable, the tool could be used to convince the patient to adopt lifestyle changes or to forgo implant therapy.

Material and Methods

Protocol

A systematic search of the scientific literature was conducted according to the recommendations of the Cochrane Collaboration[7] and the principles of the PRISMA 2020 statement.[8]

Search Strategy

The electronic databases PubMed (via Medline) and Embase (via Ovid) were screened for literature published in English before August 2021. The following search strategy, including MeSH terms, was performed in all databases, when possible and within the rules of each database:

("peri-implantitis"[Mesh] OR "periimplantitis"[tiab]
OR "peri-implantitis"[tiab] OR "perimplantitis"[tiab] OR "peri implantitis"[tiab])
AND
("Risk Factors"[Mesh] OR "risk factor"[tiab] OR "risk factors"[tiab] OR “risk”[tiab]
OR "indicator"[tiab] OR "indicators"[tiab]
OR "predictor"[tiab] OR "predictors"[tiab] OR "predictive"[tiab]
OR "etiology" [Subheading] OR "etiology"[tiab] OR "etiologies"[tiab]
OR "Association"[Mesh] OR "association"[tiab] OR "associated"[tiab]
OR "prevent"[tiab] OR "prevents"[tiab] OR "prevention"[tiab] OR "preventing"[tiab]
OR "related"[tiab] OR "relation"[tiab]
)

References of systematic reviews, meta-analyses, and included studies were screened for potential missing articles. A manual search was performed of issues of the last 10 years of the following journals: Journal of Periodontology, International Journal of Periodontics and Restorative Dentistry, Journal of Clinical Periodontology, Journal of Dental Research, Journal of Periodontal Research, Journal of Dentistry, Clinical Oral Investigations, Clinical Oral Implant Research, and Clinical Implant Dentistry and Related Research.

Study Selection Process

Two reviewers (MT and MQ) completed the selection process independently. Discrepancies regarding the inclusion or exclusion of studies were resolved by consensus. For the primary analysis, only systematic reviews were considered. However, in order not to miss potentially relevant risk factors, prospective as well as retrospective trials evaluating risk factors not covered by the systematic reviews were also selected and will be discussed separately.

All studies had to satisfy the following inclusion criteria:

studied human subjects above 18 years of age,

must be controlled (comparing at least two different treatments/patient cohorts),

data regarding prevalence, odds ratio (OR), relative risk (RR) and/or standard score (z) for peri-implantitis must be reported,

have at least 10 participants per group,

have at least 6 months of follow up.

When multiple papers from the same research group were identified, care was taken to ensure the inclusion of only the paper reporting the results with the longest follow-up period. Furthermore, no restrictions regarding publication year or definition of peri-implantitis were applied.

To reduce the heterogeneity of the data, the following exclusion criteria were applied:

Zirconium, PEEK, custom-made, non-endosseous and non-screw-type implants (root-analog, blade, etc.),

short (< 8 mm) and narrow-diameter (< 3 mm) implants,

tooth-implant supported restorations,

retrograde peri-implantitis,

the socket shield technique,

major bone augmentation surgery (e.g., fibular, iliac, skin flaps, Le Fort I osteotomies),

medically compromised patients (e.g., cancer, immunosuppression, radiotherapy, genetic syndromes, Crohn's disease, congenital and acquired neurological disabilities),

patients with a history of anti-resorptive medication.

Outcome Variables

The primary outcome was patient-related risk factors for peri-implantitis, predominantly focusing on prevalence, odds ratio (OR), relative risk (RR), and/or standard score (z) for the development of peri-implantitis together with their 95% confidence interval (CI).

Treatment-related risk factors were defined as those related to the surgical and prosthetic protocol (implant surface roughness, immediate placement, cemented vs. screw-retained, abutment connection and material) or site-related characteristics which can be modified by the clinician (absence of keratinized tissue, the need to perform guided bone regeneration (GBR) at the time of placement).

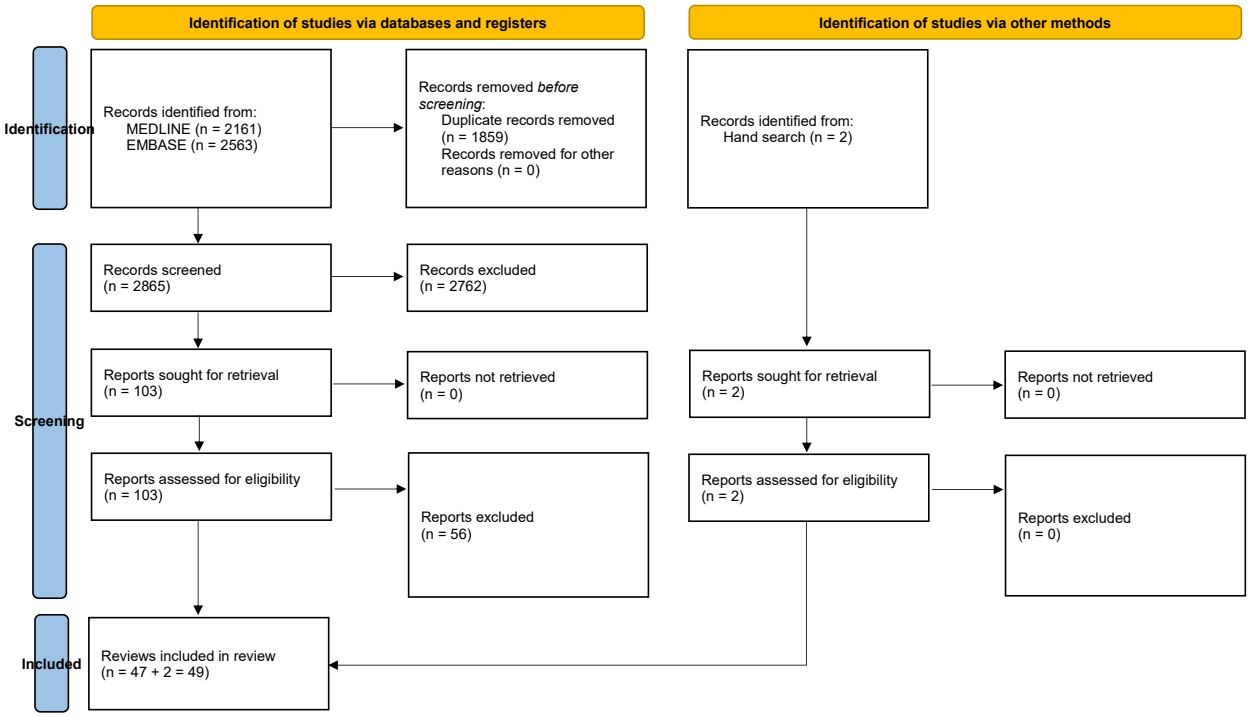
Results

Search Outcome

A total of 4724 publications were identified, 2161 in PubMed and 2563 in Embase. After removing duplicates, 2865 papers remained and after evaluating their titles and abstracts, 2762 were excluded; therefore, 103 systematic reviews were assessed for eligibility.

Of the remaining 103 systematic reviews, 56 were excluded during the selection phase. Two additional systematic reviews were identified through manual searching and included. As a result, 49 systematic reviews qualified for inclusion and are discussed below. The search workflow is illustrated in Fig 1.

Figure 1. PRISMA 2020 flowchart of search strategy. From Page et al. (2021).



Patient-Related Factors

Table 1 summarizes 30 systematic reviews (of which 15 with meta-analyses) on risk factors/indicators that could be considered in a pre-operative evaluation of the potential susceptibility of a patient to peri-implantitis. Unfortunately, most of these systematic reviews evaluated the impact of only one or just a few risk factors, mostly without taking the other identified risk factors into consideration. Moreover, while treatment-related risk factors/indicators and other confounders were very frequently identified and discussed, they were not considered in the meta-analyses themselves.

Table 6.1: Systematic reviews and meta-analyses examining "patient-related" risk factors/indicators for peri-implantitis.

Author	Analysis	# studies or design	# patients	# implants	Follow-up duration	1: History of periodontitis	2: Implant location	3: Smoking	4: BOP	5: Poor oral hygiene	6: # teeth lost	7: # PPD ≥ 5 mm	8: Recall frequency / compliance	9: Occlusal overload	10: Systemic factors	Correction for iatrogenic
SYSTEMATIC REVIEWS + META-ANALYSES																
Atieh et al. (2021)	SR+MA (patient-level)	3	479	967	72-226m								**RR 6.96[a] (2.08,23.30) *p=0.002***			
	SR+MA (implant-level)	2	138	603	12-68.2m								**RR 1.53[a] (1.13,2.08) *p=0.006***			
Song et al. (2020)	SR+MA (implant-level)	10	2091	6262	1-17y		**RR 1.34[b] (1.07,1.69) *p=0.01***									
	max. ant. vs. max. post.	7	NR	1466	56m-17y		**RR 1.37[c] (1.10, 1.71) *p=0.005***									
	mand. ant. vs. max. post.	7	NR	1345	56m-17y		**RR 1.76[c] (1.29,2.42) *p=0.0004***									
	max. ant. vs. mand. post.	7	NR	1676	56m-17y		RR 1.15[d] (0.75,1.75) *p=0.53*									
Lin et al. (2019)*	SR+MA (patient-level)	3	218	> 246 (2 NR)	48-68.5m								**RR 0.25 (0.13,0.48) *p<0.001***			
Dreyer et al. (2018)[f,p]	SR+MA	57	8-1350 / study	NR	1y - >10y	↑	?	**OR 1.7 (1.25,2.3)**				↑	↑		**OR 2.5[g] (1.4,4.5)**	KT, surface
Ferreira et al. (2018)[h]	SR+MA (patient-level)	19	4322	10075	1y-16.5y	**OR 2.29 (1.34,3.24)**										
Lee et al. (2017)	SR+MA (implant-level)	47	6422	> 19883 (2 NR)	3-16.4y	0.08 (-0.01,0.17) *p=0.08*		**0.16 (0.00,0.31) *p=0.04***								surface, prosthesis, immediate
	SR+MA (patient-level)	47	6422	> 19883 (2 NR)	3-16.4y	0.10 (-0.14,0.33) *p=0.39*		0.24 (-0.10,0.58) *p=0.16*								surface, prosthesis, immediate
Monje et al. (2017)[i]	SR+MA	7	1,442	> 1888 (2 NR)	6m-11.8y										**RR 1.46[g] (1.21,1.77) OR 1.8[g] (1.31,2.46)**	surface
	non-smokers	3	321	706	6-60m			*NS only*							**RR 3.39[g] (1.06,10.81)**	surface
Monje et al. (2016)[k]	SR+MA (implant-level)	13	1370	> 3992 (1 NR)	12-192m	**z = -14.64 *p<0.001***							**z = -29.31[l] *p<0.001***			surface
	SR+MA (patient-level)	13	1370	> 3992 (1 NR)	12-192m	**z = 3.79 *p<0.001***							**z = -3.94[l] *p<0.001***			surface
Stacchi et al. (2016)	SR+MA (perio.) (implant-level)	3[j]	168	518	> 3y	**RR 0.23 (0.11,0.46) *p<0.0001***										
	SR+MA (perio.) (patient-level)	2	115	406	> 3y	**RR 0.25 (0.07,0.88) *p=0.003***									*no uncontrolled diabetes, osteoporosis*	only titanium

The following risk factors were found to increase patients' susceptibility to peri-implantitis significantly in at least one meta-analysis:

history of periodontitis,[9–22]

implant location,[10,11,23]

smoking,[9,11,13,14,21,22,24–29]

number of teeth lost,[30]

compliance with recall appointments,[9,11,15,19,21,29,31–33]

presence of systemic disease, specifically diabetes.[11,13,27,34–37]

For the following factors, an increased incidence of peri-implantitis has been reported in systematic reviews, but no meta-analyses were available:

bleeding on probing (BOP),[28]

poor oral hygiene,[13]

number of sites with probing pocket depth (PPD) ≥ 5 mm,[11,21,28,29]

occlusal overload.[38]

Finally, the following factors have been investigated in systematic reviews, but their impact was not significant, or the evidence was limited or unclear:

Age,[11]

Gender,[11]

Edentulism,[10,11]

the use of chemical agents during supportive periodontal therapy,[32]

other systemic diseases:

cardiovascular disease,[27,36]

rheumatoid arthrythis, lung disease, obesity, cancer, depression,[27]

osteoporosis.[11,27]

alcohol consumption.[13]

Treatment-Related Factors and Additional Confounders

Table 2 summarizes 19 systematic reviews (of which 9 with meta-analyses) on treatment-related factors that might modify patients' susceptibility for peri-implantitis, and could be used to change the treatment strategy. Again, most of these systematic reviews investigated the impact of only one or just a few factors, mostly without taking the other identified risk factors into consideration.

Table 6.2: Systematic reviews and meta-analyses examining "treatment-related" risk factors/indicators for peri-implantitis.

Author	Analysis (if multiple)	# studies or design	# patients	# implants	Follow-up duration	1: Surface roughness	2: GBR at placement	3: Keratinized tissue	4: Abutment material	5: Abutment connection	6: Cemented restoration	7: Prosthetic suprastructure	8: Placement strategy
SYSTEMATIC REVIEWS + META-ANALYSES													
Nagay et al. (2021)	SR+MA					*anodized implants only*							
	FPD, (implant-level)	2	74	310	3-5y							RR 0.77[a] (0.19, 3.08) *p=0.71*	
	SC, (patient-level)	2	100	100	3-5y							RR 0.85[a] (0.28, 0.61) *p=0.78*	
	FPD, (patient-level)	1	24	160	3y							RR 0.33[a] (0.01, 7.78) *p=0.49*	
	SC+FPD, (patient-level)	3	124	260	3-5y							RR 0.75[a] (0.26, 2.12) *p=0.58*	
Lemos et al. (2020)[b]	SR+MA	10	453	770	6 - 102m								RR 1.10[c] (0.70,1.73) *p=0.67*
Jordana et al. (2018)[d]	SR+MA	22	1,787	5,183	3-20y	**minimally: 0.57 moderately: 3.43 rough: 12.86 p<10[-6]**							
Rakic et al. (2018)[e]	SR+MA (implant-level)	18	3136	9276	1-23y	**minimally: 0.19 moderately: 0.05 rough: 0.18 *p=0.011***							
	SR+MA (patient-level)	12	3,516	> 7435 (2 NR)	1-22y	**minimally: 0.16 (0.099,0.214) moderately: 0.06 (0.022,0.096) rough: 0.19 (0.132,0.246)**							
Salvi et al. (2018)	SR+MA (implant-level)	10	NR	642	≥ 10y		7.5% (2,13) vs. 9.7% (4,15)[f]						
	SR+MA (patient-level)	11	351	NR	≥ 10y		10.3% (4,17) vs. 17.8% (0,37)[f]						
Esposito et al. (2014)[g]	SR+MA (3y)	4	144	NR	3y	**RR 0.80[h] (0.67,0.96) *p=0.01***							
	SR+MA (5y)	1	66	NR	5y	n.s.							
	SR+MA (10y)	1	83	NR	10y	n.s.							

The following factors were found to significantly increase patients' susceptibility to peri-implantitis in at least one meta-analysis:

implant surface roughness,[39–44]

prosthetic suprastructure characteristics: crown-to-implant ratio[45] or suprastructure type.[46,47]

For other factors, only higher tendencies (or non-significant OR/RR data) were observed:

GBR at implant placement,[48]

lack of keratinized tissue,[49]

abutment material (metal vs. ceramic),[50]

abutment connection (external vs. internal),[50]

cement remnants,[51–55]

surgical strategy (immediate vs. delayed placement).[56,57]

Discussion

Because of the high prevalence of peri-implantitis and the difficulty of its treatment, prevention becomes primordial. Optimal patient selection and evidence-based data on which risk factors should be modified in order to reduce patient susceptibility (e.g. smoking cessation, improved oral hygiene, strict adherence to supportive periodontal and peri-implant maintenance therapy) might reduce the tsunami of peri-implantitis cases.

Patient-Related Factors

A history of periodontitis,[9–22,25] number of teeth lost (especially those due to periodontitis)[30] are also good indicators for patients' susceptibility to intra-oral infections including peri-implantitis. Moreover, the ratio of bone loss divided by the patient's age is a good estimation of patients' susceptibility to the intra-oral microbiota, as clearly indicated for teeth,[58] but seldomly used for implants.[25] The evidence for edentulism[11] is inconclusive.

Periodontal health, as expressed through number of sites with PPD ≥ 5 mm[11,28,29] and BOP scores,[28] can influence the intra-oral bacterial composition/load, and should be addressed prior to implant therapy.

Patient compliance and willingness to maintain adequate oral hygiene, as expressed through plaque scores[13] and regular attendance of recall appointments, [9,11,15,19,21,27,29,31–33] for supportive periodontal and peri-implant maintenance therapy was also identified as important. A stringent follow-up has been proposed to reduce the risk for peri-implantitis.[4]

The latest consensus considers evidence on the effect of smoking on peri-implantitis unclear,[4] there are however a number of reviews which indicate an association.[9,11,13,14,21,24–29]

It is also worth considering that its impact on periodontitis has been demonstrated to be undeniable.[59]

A single systematic review indicated that occlusal overload may have a negative impact.[38]

Systemic diseases such as diabetes clearly increase patient susceptibility to peri-implantitis.[11,35] Evidence for associations with other systemic diseases is currently lacking.

Finally, implant location may also have an effect, with one systematic review suggesting that implants placed in the upper jaw may be at higher risk for peri-implantitis.[10]

Treatment-Related Factors

When one would like to "pre-operatively" predict patient susceptibility to peri-implantitis, a number of other risk factors and confounders must be considered. Rough implants, as defined by Albrektsson & Wennerberg in 2004, are significantly more prone to peri-implantitis than moderately/minimally rough implants,[39–42] probably because of their enhanced plaque formation.[61]

The characteristics of the prosthodontic restoration may also play an important role. Several systematic reviews have found a higher risk for peri-implantitis for cemented restorations,[51–54] when compared to screw-retained, however the only meta-analysis on the topic failed to identify a statistically significant association.[55] Interestingly, it is unclear whether the impact of abutment material and/or internal vs. external abutment-implant connection[50] is significant. There is limited evidence that an increase in crown-to-implant ratio[45] may have a protective role against peri-implantitis, and the type of prosthetic suprastructure (single crown, FPD or full-arch bridge, overdenture) may also play a role, with splinted crowns and full-arch fixed dental prostheses potentially increasing the risk.[46,47,54]

Treatment strategy also seems to have an impact, with a slightly increased susceptibility when guided bone regeneration had to be performed.[48] It is unclear whether a flapless approach 56 or the timing of implant placement[57] play a role, while the presence of an adequate zone of keratinized, immobile peri-implant mucosa does seem to be important for the maintenance of peri-implant health.[49]

This review does suffer from several limitations, which should be considered when interpreting the results:

a lack of uniformity in the definition of peri-implantitis, as bone level diagnostic thresholds can have a large impact on prevalence,[25]

a lack of uniformity in the definition/criteria/threshold of the confounding factors,

a lack of multifactorial analyses (modeling), in order to verify the relative contribution of each factor when all other factors are considered; while the interaction of different risk factors most likely plays an important role in the development of the disease, to our knowledge very few studies (Jemt, 2017) and no systematic reviews have investigated this, making an umbrella review which considers the interaction impossible at the present time,

the relationship between modifiable and non-modifiable risk factors may also be crucial to better understanding the development of the disease, however such studies would require larger sample sizes and at least 4 subgroups, and to our knowledge no reviews of such studies currently exist,

heterogeneity of study designs: odds ratio/relative risk values are associated with study design, with tendency for higher values for randomized-controlled versus cohort versus case-control versus cross-sectional,[12] it is very difficult or impossible to perform randomized controlled trials for establishing some risk factors, meaning that several of the meta-analyses included, even if of the highest quality, can only be based on observational or retrospective findings, introducing biases and limiting their general applicability, more recently discovered

risk factors may not yet have enough evidence to have warranted a systematic review, meaning they have not been included here.

This review identifies risk factors that significantly influence patients' susceptibility to peri-implantitis. Because of the limited data available and its heterogeneity, its implications and the clinical guidelines that can be derived from it are limited. It can, however, be useful to identify current gaps in the literature and serve as a starting point for future clinical studies. The ultimate goal was to develop a software tool for the clinician, but especially for the patient, to "pre-operatively" estimate the risk for peri-implantitis, and to identify potential modifiable factors to reduce this risk (see part 2).

Conclusions

Based on 30 systematic reviews (15 with meta-analyses), a total of 10 relevant patient-related risk factors/indicators were identified. Unfortunately, in most of these reviews only one or just a few of these factors were analyzed simultaneously, so that the relative impact of each risk factor remains unpredictable. Moreover, treatment-related factors increasing patient susceptibility to peri-implantitis, for which analyses should be corrected, were often not considered. As such it was simply impossible to estimate the relative importance of each risk factor.

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Conflict of interest:

All (co)-authors declare that they have no conflict of interest. The department of periodontology owns research chairs from several implant companies: Dentsply Sirona, Straumann, Henry Schein.

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