Prevalence of Peri-implant Diseases in Patients with Full-Arch Implant-Supported Restorations: A Systematic Review

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Purpose: To assess the prevalence of peri-implant diseases (ie, peri-implant mucositis and peri-implantitis) in patients rehabilitated with full-arch, implant-supported restorations. ***Materials and Methods:*** A search protocol was developed to answer the following focus question: What is the prevalence of peri-implant diseases in edentulous patients rehabilitated with implant-supported fixed or removable restorations? RCTs, controlled clinical trials, and prospective studies with at least 12 months of follow-up and a minimum of 10 patients having at least one edentulous arch were searched. ***Results:*** A total of 18 studies (3 RCTs, 1 nonrandomized controlled trial, and 14 prospective studies) were included. According to a single study, the prevalence of peri-implant mucositis in fully edentulous patients was 57%, corresponding to 47% at the implant level. The prevalence of peri-implant mucositis among patients having at least one edentulous arch ranged between 0% and 13.7% of patients, and from 0% to 20% of implants. In fully edentulous patients, the prevalence of peri-implantitis was found to range between 1.5% and 29.7% of patients and between 2.1% and 20.3% of the implants, while the corresponding values among the patients with at least one edentulous arch were 0% to 25% and 0% to 7.2%, respectively. ***Conclusion:*** Edentulous patients (fully edentulous or at least one edentulous arch) restored with either fixed or removable restorations were frequently affected by peri-implant disease. *Int J Prosthodont 2021;34(suppl):s27–s45. doi: 10.11607/ijp.6488*

Biologic complications affecting osseointegrated dental implants have been classified as peri-implant mucositis and peri-implantitis.[1] Both diseases exhibit clinical signs of inflammation in the soft tissues surrounding an endosseous implant, while peri-implantitis also includes a progressive loss of supporting bone.[1] In fact, it is assumed that peri-implant mucositis is the precursor to peri-implantitis.[2]

Although peri-implant diseases are primarily caused by a bacterial challenge,[3] a number of factors have been identified that may increase the probability of their development.[4,5] Particularly, smoking and radiation have been found to be associated with peri-implant mucositis, and patients with a history of chronic periodontitis, poor plaque control skills, and no regular maintenance care after implant placement were reported to be at a higher risk of developing peri-implantitis.[5] Moreover, factors such as submucosal cement remnants, lack of keratinized mucosa, and improper implant positioning not allowing for proper oral hygiene and maintenance were designated as local risk factors for peri-implantitis.[5]

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Previous clinical studies have demonstrated that the microbial compositions of the neighboring teeth resemble the composition found at the peri-implant sulcus.[6–8] Furthermore, the presence of inflammation around teeth was shown to be associated with peri-implantitis around the neighboring implants.[6] Considering the fact that chronic periodontitis is a risk factor for peri-implantitis, some studies have claimed that the colonization of dental implants by periodontopathogens in partially edentulous patients could increase the risk of peri-implantitis occurrence.[9,10] As a consequence, it might be hypothesized that the occurence of peri-implant disease may differ between partially and fully edentulous patients.[10,11]

Therefore, the aim of this systematic review was to assess the prevalence of peri-implant diseases (ie, peri-implant mucositis and peri-implantitis) in patients rehabilitated with full-arch implant-supported fixed or removable restorations.

MATERIALS AND METHODS

The review protocol was developed according to the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analyses) statement.[12]

Focus Question

The following question was developed according to the PICO (population, intervention, comparison, and outcome) formulation: What is the prevalence of peri-implant diseases (ie, peri-implant mucositis and peri-implantitis) in edentulous patients rehabilitated with implant-supported fixed or removable restorations? The components were as follows:

- Population: patients with at least one edentulous arch
- Intervention: rehabilitation with complete implant-supported fixed or removable restorations in mandible or maxilla
- Comparison: not applicable
- Outcome: prevalence of peri-implant mucositis and peri-implantitis

Search Strategy

Two electronic databases (MEDLINE via PubMed and the Cochrane database) were searched for relevant articles published up to February 1, 2019. The search was limited to studies in humans and in the English language.

In addition, a hand search was performed including reference lists of all full-text articles and the following scientific journals: *Clinical Oral Implants Research*, *Clinical Implant Dentistry and Related Research*, *European Journal of Oral Implantology*, *Implant Dentistry*, *The International Journal of Oral & Maxillofacial Implants*, *The International Journal of Periodontics & Restorative Dentistry*, *Journal of Clinical Periodontology*, *Journal of Oral Implantology*, *International Journal of Oral & Maxillofacial Surgery*, *Journal of Periodontology*, *Journal of Prosthetic Dentistry*, *The Open Dentistry Journal*, and *Journal of Implant and Advanced Clinical Dentistry*.

The following search terms were used:

- Population: edentulous jaws [Mesh term] OR edentulous maxilla [Mesh term] OR edentulous mandible [Mesh term] OR edentulous ridge [Mesh term] OR complete edentulism [Mesh term]
- Intervention: dental prostheses, implant supported [Mesh term] OR implant supported dentures [Mesh term] OR implant [Mesh term] OR overdenture [Mesh term] OR overdentures [Mesh term] OR complete dentures [Mesh term] OR full arch [Text word] OR fixed complete prostheses [Text word]
- Outcome: periimplantitis [Mesh term] OR peri-implantitis [Text word] OR peri-implant infection [Text word] OR periimplant infection [Text word] OR peri-implantitis [Text word] OR biological complications [Text word] OR mucositis [Mesh term]
- Population AND Intervention AND Outcome

Selection of Studies

During the first literature selection stage, the titles and abstracts of all identified studies were screened for eligibility by two independent reviewers (A.R. and M.E.G). The following inclusion criteria were applied:

- Randomized controlled trials (RCTs), controlled clinical trials (CCTs), and prospective studies with at least 12 months of follow-up with a minimum of 10 patients having at least one edentulous arch rehabilitated with implant-supported fixed and/or removable restorations in the maxilla and/or mandible reporting on the prevalence of peri-implant mucositis and/or peri-implantitis
- Studies specifying definitions for peri-implant mucositis and/or peri-implantitis
- Studies with solid screw-type titanium implants that were placed immediately or delayed (Type I–IV implant placement[13])

At the second stage, the full texts of potentially eligible articles were reviewed and evaluated according to the following exclusion criteria:

- Animal studies
- Case series, retrospective studies, case reports, and cross-sectional studies
- Studies using mini-implants (≤ 3 mm diameter) and/or short implants (≤ 6 mm)
- Studies with a follow-up period of < 1 year
- Studies including < than 10 patients

- Studies with no definitions of peri-implant mucositis and/or peri-implantitis
- Studies reporting on zirconia or other implant material besides titanium
- Studies reporting on zygomatic implants
- Articles published in language other than English

Differences between reviewers were resolved by discussion and consensus. The level of interexaminer agreement for the first and second literature selection stages was expressed by Cohen κ score.

Data Extraction

From the selected articles fulfilling the inclusion criteria, the following data were retrieved into predefined tables:

- General information: study design, follow-up period, setting, number of patients and implants, arch (maxilla/mandible), and patient-related information, including age, gender, smoking status, history of periodontitis, and maintenance program (Table 1)
- Implant and prosthodontic design–related data: implant type/brand, distribution and/or number of implants placed per arch, bone augmentation procedures, time of implant placement (immediate/delayed), two- or one-stage implant placement, prosthodontic design (removable/fixed), opposing dentition, and loading protocol (conventional/delayed) (Table 2)
- Treatment outcomes: definitions of peri-implant diseases, prevalence of peri-implant mucositis and/or peri-implantitis, and additional observations related to the prevalence of peri-implant diseases (Tables 3a and 3b)

Quality Assessment

The Cochrane Collaboration's tool for assessing risk of bias was used for CCTs.[14] The following items were evaluated as posing a low, high, or unclear risk of bias: *(1)* random sequence generation; *(2)* allocation concealment; *(3)* blinding of participants/personnel; *(4)* blinding of outcome assessors; *(5)* incomplete outcome data; *(6)* selective reporting outcomes; and *(7)* other potential risks of bias. The degree of bias was categorized as low risk if all criteria were met, moderate when one criterion was missing, and high if two or more criteria were missing.

For studies with controls (ie, observational studies), methodologic quality assessment was based on the Risk of Bias In Non-randomized Studies—of Interventions (ROBINS-I) tool.[15] The following domains were evaluated as posing a low, moderate, serious, or critical risk of bias: *(1)* bias due to confounding; *(2)* bias in selection of participants; *(3)* bias in measurement of interventions; *(4)* bias due to deviations from intended interventions; *(5)* bias due to missing data; *(6)* bias in measurement of outcomes; and *(7)* bias in selection of the reported results. The first two domains address issues before the start of the intervention(s), whereas the third domain addresses classification of the intervention(s) themselves. The rest of the domains address issues after the start of the intervention(s). The study was judged to have an overall low risk of bias if all domains appeared to have a low risk, a moderate risk if all domains had a low or moderate risk of bias, a serious risk if at least one domain was judged to have a serious risk of bias but no critical risk of bias in any domain, and critical risk if at least one domain was judged to have a critical risk of bias.

Data Synthesis

The evaluation of the selected studies revealed considerable heterogeneity with respect to study design, definitions applied, and assessment of clinical and radiographic parameters. Therefore, it was not possible to conduct a quantitative data synthesis. Instead, the authors attempted to perform a descriptive analysis of the collected data.

RESULTS

Search

The electronic search yielded 1,336 titles. Ten additional articles were identified through the hand search, rendering an initial search selection of 1,346 records. Following the screening of titles and abstracts, 75 articles were selected for full-text analysis (κ = 0.96; Fig 1). An additional 56 articles were excluded, resulting in a final selection of 19 articles (κ = 1). Two of the studies included the same patient sample that was evaluated at different follow-up periods[16,17]; therefore, a total of 18 original clinical investigations were included. The excluded studies and reasons for their exclusion are presented in Appendix 1 (see appendix in the online version of this article at www.quintpub.com/journals).

Study Characteristics

The included studies are described in Tables 1 and 2. Of 18 relevant studies, 3 were RCTs,[18–20] 1 was a CCT,[21] and 14 were prospective clinical studies.[16,22–34] The mean follow-up period ranged from 1 year[21,30,31] to up to 10[22,24,26] and 11.26 years.[25] Four studies[16,29,30,33] reported on patients treated in a private practice setting, while in the rest of the investigations, the patients were treated in a university setting.

Risk of Bias Within the Studies

According to the Cochrane Collaboration tool, the included RCTs were judged to have an overall unclear risk of bias according to two,[18] three,[20] or four domains[19] (Table 4a). In all of the studies, the critical domains that were judged to have an unclear risk of bias appeared to be random sequence generation and blinding of

Table 1 General Information Extracted from Included Studies

Study, y	Study design	Follow-up period	Setting	Patients, n	Treated arch	Implants, n
Slot et al,[18] 2019	RCT *	5 y	University	60 4-implant group: 29 6-implant group: 31	Maxilla; fully edentulous patients with insufficient bone volume in the maxilla (< 3 mm in width, and < 5 mm in height)	302 4-implant group: 116 6-implant group: 186
Windael et al,[23] 2018	Prospective	10 y	University	21	Mandible	105 All patients received 5 implants in the interforaminal region
Li et al,[28] 2017	Prospective	5 y (range: 2–7 y)	University	17	Maxilla: 7 Mandible: 13	80 Maxilla: 28 Mandible: 52
Zhang et al,[26] 2016	Prospective	10 y	University	11	Maxilla	83
Slot et al,[19] 2016	RCT	5 y	University	46 4-implant group: 24 6-implant group: 22	Maxilla (fully edentulous patients with sufficient bone volume in the anterior area between bicuspids (at least 12-mm height and at least 5-mm width)	228 4-implant group: 96 6-implant group: 132
Krennmair et al,[27] 2016	Prospective	3 y	University	37	Mandible	148
Cannizzaro et al,[16,17] 2014, 2018	Prospective	5 y	Private practice	80	Mandible	160
Meijer et al,[22] 2014	Sub-analysis of two prospective studies	10 y	University	150 (10 patients did not attend the 5-year evaluation, and 29 did not attend the 10-year evaluation, leaving a final sample size of 111)	Mandible	300 5-y follow-up: 276 implants 10-y follow-up: 240 implants
Peñarrocha-Oltra et al,[21] 2014	Prospective, controlled, nonrandomized	1 y (range: 12–36 mo)	University	29 Test (immediate loading): 14 Control (conventional loading): 15	Maxilla with sufficient bone height and width to place 6 to 8 implants (at least 10-mm length and 3.8-mm diameter with ≥ 35 Ncm torque)	193 Fresh sockets: Test: 49 Control: 56 Healed sockets: Test: 45 Control: 43 implants
Lopes et al,[32] 2015	Prospective	5 y	University	23	Maxilla: 18 Mandible: 5	92 Maxilla: 72 Mandible: 20
Degidi et al,[33] 2013	Prospective	6 y	Private practice	52	Maxilla and mandible	256 Maxilla: 144 Mandible: 112
Mertens et al,[25] 2012	Prospective	11.26 y (range: 10.42–12.25 y)	University	15	Maxilla with sufficient bone to place 6 to 8 implants (at least 9 mm long)	94
Stoker et al,[20] 2012	RCT	8.3 y	University	94	Mandible	256
Fischer and Stenberg[24] 2012	Prospective	10 y	University	23	Maxilla	139

RCT = randomized controlled trial; NR = not reported.

Mean age (range), y	Gender (M/W)	Systemic condition	Patient smoking habit	History of periodontitis	Maintenance program
4-implant group: 61.6 (7.1, 43–74) 6-implant group: 58.7 (9.7, 34–77)	4-implant group: 23/10 6-implant group: 10/23	Systemically compromised patients excluded	Current smokers excluded	NR	All patients were scheduled for routine yearly maintenance appointments
68.3 (49–84)	8/13	No patient exclusion criteria applied. One patient underwent active cancer treatment.	Smoker: 1 patient Former smokers: 6 patients	Patients with a history of periodontitis were included (n = 11)	NR
39.4 (28–45 y)	10/7	Systemically compromised patients excluded	Heavy smokers excluded (> 15 cigarettes/d)	Only patients with advance generalized aggressive periodontitis were included	NR
56.3 (40–73)	4/8	Systemically compromised patients excluded	Heavy smokers excluded (>10 cigarettes/d)	NR	NR
4-implant group: 59.7 (46–80) 6-implant group: 57.4 (39–71)	4-implant group: 15/10 6-implant group: 8/17	Systemically compromised patients excluded	Smokers excluded	NR	NR
62.9 ± 10.1	21/20	Systemically compromised patients excluded	Heavy smokers excluded (> 10 cigarettes/d)	Untreated periodontitis in opposite arch excluded	Patients enrolled in a regular hygiene program (once/y)
53.2 (29–85)	40/40	Systemically compromised patients excluded	Smokers included: 42.5% of patient sample	Periodontitis patients were excluded	Patients were recalled for maintenance every 6 mo
56.1 (34–79)	53/97	Systemically compromised patients excluded	NR	NR	Oral hygiene instructions given at the time of overdenture placement, after 6 mo, after 12 mo, and later, on a yearly basis. If plaque was present, an additional visit was planned after 3 mo.
55.4±9.8 (28–77)	13/16	Systemically compromised patients excluded	Smokers excluded	Periodontally compromised patients included	Professional oral hygiene was performed at 6 and 12 mo
55.4 (34–70 y)	10/13	Systemtically compromised patients included	NR	NR	NR
62 ± 10.2 (45–79)	NR	Systemically compromised patients excluded	NR	NR	Maintenance visits after 6 mo, after 12 mo and later, on a yearly basis
55.3 ± 7.9	5/10	Systemically compromised patients excluded	Smokers: 40%	NR	Maintenance visits after 6 mo, after 12 mo, and later, on a yearly basis.
59.8	28/66	NR	Smokers included; 59 nonsmokers, 35 smokers	NR	NR
64	8/16	NR	NR	NR	NR

Table 1 General Information Extracted from Included Studies *(continued)*

Study, y	Study design	Follow-up period	Setting	Patients, n	Treated arch	Implants, n
Bergkvist et al,[29] 2009	Prospective	2 y, 8 mo	2 private practices	28	Maxilla	168
Testori et al,[30] 2008	Prospective	1 y	3 private practices	30	Maxilla	180
Astrand et al,[34] 2004	Prospective	5 y	University	66	Maxilla and mandible	371 Maxilla: 211 Mandible: 160
Astrand et al,[31] 2000	Prospective	1 y	University	28	Maxilla	167

RCT = randomized controlled trial; NR = not reported.

Table 2 Implant and Prosthodontic Design–Related Information Extracted from Included Studies

Study, y	Implant brand/ surface	Implant distribution and no. of implants	Bone augmentation procedures
Slot et al,[18] 2019	Straumann Standard SLA, 4.1-mm diameter, 12-mm length	Positions of implants in case of 6 implants: 16, 15/14, 13, 23, 24/25, 26 (n = 116) Positions of implants in case of 4 implants: 16, 13, 23, 26 (n = 186)	Bilateral maxillary sinus augmentation with bone from iliac crest 3 mo prior to implant placement
Windael et al,[23] 2018	Fluoride-modified implant (OsseoSpeed, Dentsply Sirona)	5 implants in interforaminal region	None
Li et al,[28] 2017	44 Brånemark MKIII 8 Nobel Speed Groovy 28 Nobel Active (Nobel Biocare)	4 implants Anterior = lateral incisor region (100% of anterior implants) Posterior = tilted implants in the first and second premolar and first molar regions (70% of posterior implants in second premolar site)	None
Zhang et al,[26] 2016	Straumann SLA	6 to 8 implants Anterior = 44 Premolar sites = 24 Molar sites = 23	No (patients in need of bone augmentation procedures were excluded)
Slot et al,[19] 2016	OsseoSpeed 4.0 S (Dentsply Sirona) At least 4-mm diameter and 11-mm length	Position of implants in case of 6 implants: 15, 13, 11, 21, 23, 25 Positions of implants in case of 4 implants: 13, 11, 21, 23	Small dehiscences or fenestrations were covered with autogenous bone + xenogenous bone (Bio-Oss) + resorbable membrane (Bio-Gide) 4-implant group: 14 patients/32 implants 6-implant group: 9 patients/18 implants

FE = fully edentulous; IMZ = intramobile cylinder; NR = not reported; PE = partially edentulous; SLA = sandblasted, large grit, acid-etched; TPS = titanium plasma spray.

Mean age (range), y	Gender (M/W)	Systemic condition	Patient smoking habit	History of periodontitis	Maintenance program
63	15/13	Systemically compromised patients excluded	Patients were asked to stop smoking before surgery and during the healing period	NR	A dental hygienist checked the patients every 6 mo
59.2 ± 9.5	26/15	Systemically compromised patients excluded	Light smokers: 12 Heavy smokers: 3	70.7% of the patients had a history of periodontitis	NR
61.5 (35–74)	NR	Only systemically healthy patients were included	NR	NR	NR
57	11/17	Systemically compromised patients excluded	Smokers: 14 patients	NR	NR

Immediate/delayed implant placement, one- or two-stage procedure	Fixed/ removable prosthesis	FE or PE opposing dentition	Loading protocol
Delayed, two stage	Bar-supported overdenture Antagonist: mandibular 4-implant overdenture	FE	Conventional, 3 mo after surgery
Delayed, one stage	Fixed full-arch screw-retained	FE	Immediate
Immediately after extraction (35 Ncm torque on all implants)	Fixed full-arch screw-retained	FE and/or PE	Immediately after implant placement Permanent fixed prosthesis placed 4–6 mo later
Delayed, two stage	Fixed full-arch cement-retained	FE and PE	Early, 6 wk after surgery
Delayed, two stage	Bar-supported overdenture Antagonist: mandibular 4-implant overdenture	FE	Conventional, 3 mo after surgery

Table 2 Implant and Prosthodontic Design–Related Information Extracted from Included Studies *(continued)*

Study, y	Implant brand/ surface	Implant distribution and no. of implants	Bone augmentation procedures
Krennmair et al,[27] 2016	Camlog, Screw-Line, Promote Plus (BioHorizons)	4 interforaminal implants. Axial group: anterior = 42, posterior = 42 Tilted group: anterior = 40, posterior = 40	None (patients in need of bone augmentation procedures were excluded)
Cannizzaro et al, 2014,[17] 2018[16]	Tapered NT NanoTite (Zimmer Biomet 3i)	2 implants interforaminal position of both mandibular canine or first premolar regions	None
Meijer et al,[22] 2014	140 IMZ cylinder with TPS coating (Dentsply Sirona) 60 Brånemark screw with machined surface (Nobel Biocare) 100 ITI solid screw with TPS coating (Straumann)	Two implants in the right and left canine regions	None
Peñarrocha-Oltra et al,[21] 2014	Kohno SP (Sweden & Martina) with dual-engineered surface (zirconium airborne particle–abraded/acid-etched titanium surface at the coronal part, high-roughness, plasma-sprayed surface of the apical part)	6 to 8 implants Anterior: test = 49, control = 43 Premolar: test = 30, control = 34 Molar: test = 15, control = 22	Dehiscence and fenestration type defects were filled with either autogenous graft or beta-tricalcium phosphate.
Lopes et al,[32] 2015	Oxidized TiUnite surface (NobelSpeedy Groovy, Nobel Biocare) 4-mm diameter	4 implants Computer-guided, flapless placement, All-on-4 modality: 2 implants in the anterior region and 2 implants in the posterior region	None
Degidi et al,[33] 2013	Grit-blasted and acid-etched (Xive Plus, Dentsply Sirona)	4 implants Distribution NR	None
Mertens et al,[25] 2012	Astra Tech AB, TiOblast, (Dentsply Sirona), 3.5- to 4.0-mm diameter to 4 mm, 8- to 17-mm length, moderately rough, screw shaped	6 to 8 implants Anterior region = 56 implants Posterior region = 38	None
Stoker et al,[20] 2012	Straumann TPS ITI/Bonefit	2 (n = 60 patients) or 4 (n = 34 patients) implants per patient in the symphysial area	NR
Fischer and Stenberg,[24] 2012	Straumann SLA, 4.1-mm diameter, 8- to 12-mm length	6 implants per patient Control = 8, Test = 16	NR
Bergkvis et al,[29] 2009	Straumann, SLA solid-screw, regular neck	6 implants Region: anterior, canine, premolar	None (patients in need of bone augmentation procedures were excluded)
Testori et al,[30] 2008	Osseotite NT (Zimmer Biomet)	6 implants: 4 axial and 2 distal tilted Region: Posterior = 2 bilateral tilted implants parallel to the anterior sinus wall Anterior = 4 axial implants	No (patients in need of bone augmentation procedures were excluded)
Astrand et al,[34] 2004	Astra Tech (Dentsply Sirona) and Brånemark System (Nobel Biocare)	NR	None
Astrand et al,[31] 2000	Straumann ITI solid-screw, 4.1-mm and 3.3-mm diameter	4 to 8 implants Distribution NR	None (patients in need of bone augmentation procedures were excluded)

FE = fully edentulous; IMZ = intramobile cylinder; NR = not reported; PE = partially edentulous; SLA = sandblasted, large grit, acid-etched; TPS = titanium plasma spray.

Immediate/delayed implant placement, two- or one-stage procedure	Fixed/removable prosthesis	FE or PE opposing dentition	Loading protocol
Delayed, two stage	Fixed full-arch screw-retained	FE and/or PE FE: 6 PE: 27 Full dentition: 8	Conventional, 2 mo after surgery
Immediate and delayed, one stage	Screw-retained cross-arch prostheses	FE and/or PE	Immediate
Delayed One stage: 100 Two stage: 200	Bar-supported overdenture All patients had a conventional removable denture in the maxilla	FE	Conventional, 3 mo after surgery
Immediate: 94 Delayed, two stage: 99	Fixed full-arch, metal-ceramic, screw-retained	FE and/or PE Opposing arch: Natural or fixed teeth-supported = 13 patients Fixed implant-supported: 13 patients Removable: 3 patients	Conventional, 2 mo after surgery (control): 15 patients Immediate loading protocol (test): 15 patients
Delayed, one stage	Fixed full-arch screw-retained	FE	Immediate, permanent prosthesis 4 mo after
Delayed, one stage	Fixed full-arch screw-retained	Opposing dentition not specified	Immediate
Delayed, two stage	Fixed full-arch screw-retained	FE	Conventional, 6 mo after surgery
Delayed, two stage	Overdenture supported: Group 1: 2 implants (ball attachments) Group 2: 2 implants (bar) Group 3: 4 implants (triple bar)	FE	Conventional, 3 mo after surgery
Delayed, two stage	Fixed full-arch screw-retained	FE and/or PE	Conventional, time NR
Delayed, one stage	Fixed full-arch screw-retained	PE	Immediate: 24 h after implant placement Permanent fixed prostheses placed 8–22 wk after
Delayed, one stage	Fixed full-arch screw-retained	FE and/or PE	Immediate (48 h after implant placement) Permanent prosthesis: 3 mo after
Delayed, two stage	Fixed full-arch screw-retained partial dentures	FE	Conventional, 3 mo after surgery in mandible, 6 mo after surgery in maxilla
Delayed, two stage	Fixed full-arch screw-retained partial dentures	Opposing dentition not specified	Conventional, 7 mo after surgery

Table 3a Prevalence of Peri-implant Mucositis and Peri-implantitis in Studies Including Only Edentulous Patients

Study, y	Case definitions	Prevalence of peri-implant disease(s), % (n/total)	Additional observations
Slot et al,[18] 2019	Peri-implant mucositis: radiographic bone loss < 2 mm + BOP and/or suppuration Peri-implantitis: BOP and/or suppuration in combination with MBL ≥ 2 mm According to the 7th EWOP[3]	Peri-implantitis: Patient level: 4-implant group: 17.2 6-implant group: 9.7	–
Slot et al,[19] 2016	Peri-implant mucositis: radiographic bone loss < 2 mm + BOP and/or suppuration Peri-implantitis: BOP and/or suppuration in combination with MBL ≥ 2 mm According to the 8th EWOP[41]	Peri-implantitis: Patient level: 4-implant group: 8.3 6-implant group: 4.5	–
Meijer et al,[22] 2014	According to the7th EWOP[3]	Peri-implant mucositis: Patient level: After 5 y: 51.9 After 10 y: 57.0 Implant level: After 5 y: 41.2 After 10 y: 47.0 Peri-implantitis: Patient level: After 5 y: 16.9 After 10 y: 29.7 Implant level: After 5 y: 11.5 After 10 y: 20.3	–
Lopes et al,[32] 2015	Peri-implantitis: local bone defect around implant, pocket formation, BOP, and mucosa inflammation	Peri-implantitis: Implant level: 2.1 (n = 2/92) Patient level: 8.7 (n = 2/23)	–
Stoker et al,[20] 2012	Peri-implantitis: PD ≥ 6 mm and MBL ≥ 3 mm	Peri-implantitis: Implant level: 5 (n = 12/256) Patient level: 5 (n = 5/94)	Smoking doubled MBL, independent of treatment 80% (n = 4/5) of peri-implantitis cases were smokers
Mertens et al,[25] 2012	Peri-implantitis: PD > 5 mm + BOP, continuous radiolucency around implant, annual vertical loss > 0.2 mm	Peri-implantitis: Implant level: 2.12 (n = 2/94)	–
Astrand et al,[34] 2004	Peri-implantitis: suppuration + advanced bone loss	Peri-implantitis: Patient level: 1.5 (n = 1/66)	–

BOP = bleeding on probing; PD = probing depth; EWOP = European Workshop on Periodontology; MBL = marginal bone loss; NR = not reported.

Table 3b Prevalence of Peri-implant Mucositis and Peri-implantitis in Studies Including Fully and Partially Edentulous Opposing Dentition

Study, y	Case definition	Prevalence of peri-implant diseases, % (n/total)	Additional observations
Windael et al,[23] 2018	Peri-implantitis: Bone loss ≥ 2 mm + BOP and/or suppuration	Peri-implantitis: Implant level: 4.8 (5/105)	Implants showing early bone loss (≥ 0.5 mm during the first year of function) may be at higher risk of developing peri-implantitis.
Li et al,[28] 2017	Peri-implantitis: Presence of peri-implant pocket > 4 mm and ongoing bone resorption	Peri-implantitis: Implant level: 1.25 (1/80)	–
Zhang et al,[26] 2016	Peri-implantitis: MBL exceeding 3 mm in combination with BOP, suppuration, or both	Peri-implantitis: Patient level: 9 (1/11) Implant level: 1.1 (1/83)	–
Krennmair et al,[27] 2016	Peri-implant mucositis: severe soft tissue inflammation without bone loss Peri-implantitis: peri-implant bone loss with/without suppuration or severely inflamed tissue with bleeding	Peri-implant mucositis: Total implant level: 3 y: 8.1 (12/148) Axial group Implant level: 3 y: 7.9 (6/76) Tilted group Implant level: 3 y: 8.3 (6/72) Peri-implantitis: NR	Posterior implants (axial group): higher plaque and gingiva indices when compared to tilted group. No differences in biologic or mechanical complications after 3 y among groups.
Cannizzaro et al, 2014,[17] 2018[16]	Peri-implant mucositis: heavily inflamed soft tissues without bone loss Peri-implantitis: bone loss with suppuration or heavily inflamed tissues	Implant level: Peri-implant mucositis: NR Peri-implantitis: 1.25 (1/80)	–
Peñarrocha-Oltra et al,[21] 2014	According to the 7th EWOP[3]	Peri-implant mucositis: Patient level: 13.7 (4/29) Implant level: 3.6 (7/193) Peri-implantitis: 0	–
Degidi et al,[33] 2013	Peri-implant mucositis: inflammation of the mucosal cuff around the neck of the implants associated with edema, rubor, and BOP in the area Peri-implantitis: signs of infection, with suppuration and peri-implant radiologic translucency	Peri-implant mucositis: Implant level: 11.85 (25/211) Peri-implantitis: Implant level: 3.31 (7/211)	–
Fischer and Steinberg,[24] 2012	Peri-implantitis: loss of supporting bone + perfuse bleeding with suppuration	Peri-implantitis: Patient level: 4.3 (1/23)	Peri-implantitis case: patient with history of periodontitis and who smoked.
Bergkvist et al,[29] 2009	Peri-implant mucositis: bleeding as a sign of reversible plaque-induced mucosal inflammation Peri-implantitis: mucosal bleeding after gentle probing together with increased probing depth, occasional suppuration, and radiographic crestal bone loss	Peri-implant mucositis: Implant level: 12 (20/168) Peri-implantitis Implant level: 1.8 (3/168) Patient level: 7.1 (2/28)	–
Testori et al,[30] 2008	Peri-implant mucositis: heavily inflamed soft tissue in the absence of bone loss Peri-implantitis: bone loss with suppuration or heavily inflamed tissues	–	–
Astrand et al,[31] 2000	Peri-implant mucositis: positive BOP Peri-implantitis: fistula or suppuration in combination with bone loss	Peri-implant mucositis: Implant level: 3 (5/167) Peri-implantitis Implant level: 7.2 (12/167) Patient level: 25 (7/28)	5/7 patients with peri-implantitis: smokers. 3/12 peri-implantitis implants: failed despite treatment.

BOP = bleeding on probing; NR = not reported; MBL = marginal bone loss.

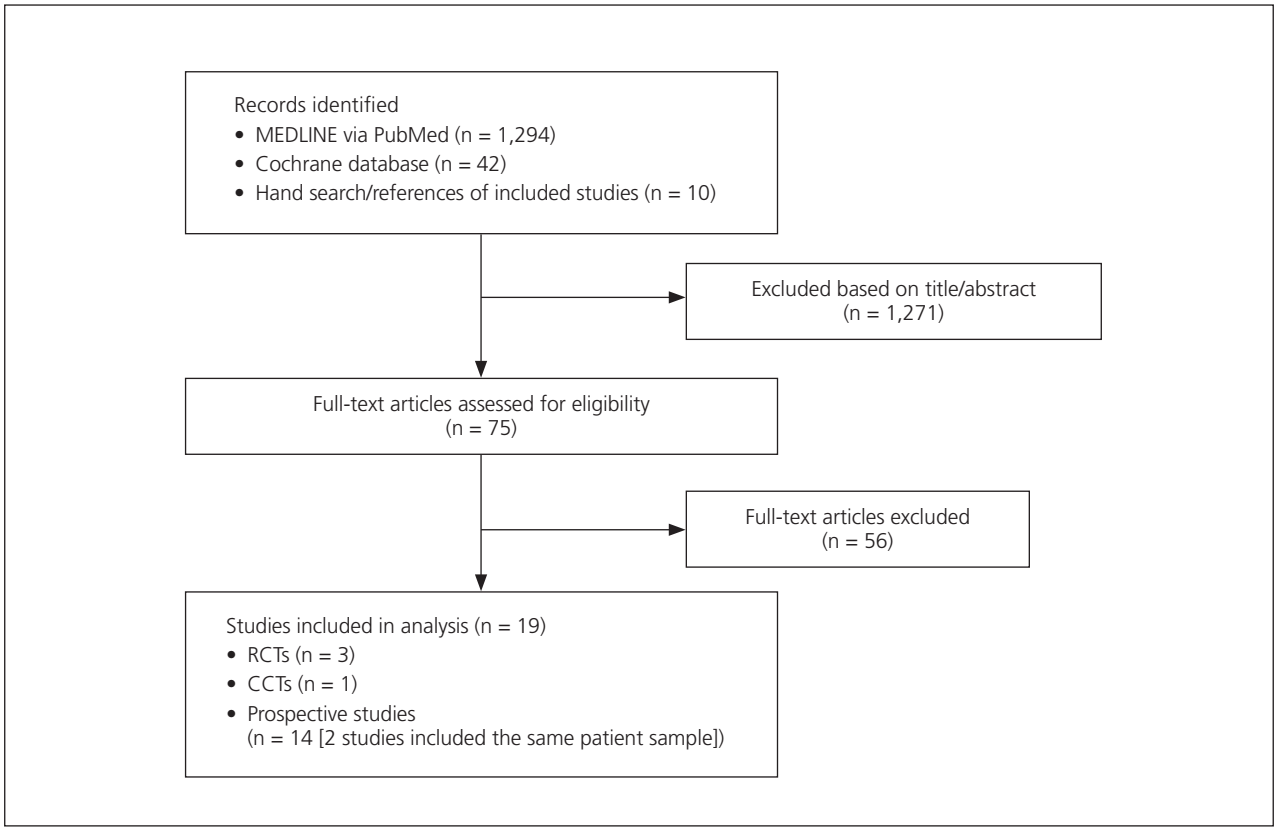

Fig 1 Flowchart of inclusion process. The interrater agreement for title and abstract screening was $\kappa = 0.96$, and for full-text screening was $\kappa = 1$.

participants/personnel.[18–20] Three domains (incomplete outcome data, selective reporting, and other bias) had a low risk of bias in all of the included RCTs.[18–20] A single CCT had an overall high risk of bias according to four domains (random sequence generation, allocation concealment, blinding of outcome assessors, and incomplete outcome data).[21]

Overall, based on the ROBINS-I tool assessments, 7 of 14 studies were judged to have a serious risk of bias according to one,[26] two,[22,23,30,32,33] or three[28] domains (Table 4b). Six studies appeared to have an overall moderate risk (according to one,[16,25,31] two,[34] or three[24,29] domains), and one study[27] was judged to have an overall high risk of bias (according to one domain). The domain of bias due to deviations from intended interventions had a low risk in all of the investigations. Similarly, of the remaining 13 articles,[16,17,22–29,31,34] all articles except for one[30] had a low risk of bias in the domain for bias in selection of the reported results. In contrast, the domains for bias due to confounding[16,22–26,28–30,32–34] and bias in measurement of outcomes[22–24,26,28–34] had a moderate to serious risk in the majority of the studies.

Patient Characteristics

In total, 810 patients having at least one edentulous arch were included. The patient sample sizes varied from 29[20] to 94[21] for the controlled studies and from 11[26] to 111[22] for the studies lacking controls. The mean age of the included patients ranged from 34.9 years[28] to 68.3 years,[23] and the ratio of included men and women varied from 0.63[30] to 0.30.[20] In nine studies, edentulous maxillae were rehabilitated with implant-supported restorations,[18,19,21,24–26,29–31] and five studies reported on edentulous mandibles.[16,20,22,23,27] In the remaining four studies, both edentulous maxillary and mandibular arches were involved.[28,32–34]

Seven of the included studies recruited only fully edentulous patients, which corresponded to 56% (454/810) of the included patient population.[18–20,22,25,32,34] The opposing dentition in the remaining studies was either partially edentulous,[29] fully or partially edentulous,[16,21,23,24,26–28,30] or was not specified.[31,33]

Thirteen studies excluded patients with systemically compromised health,[16,18,19,21,22,25–31,33] while 3 investigations also enrolled patients with systemically compromised health conditions.[23,32,34] The remaining 2 studies did not report on the patients' systemic health conditions.[20,24]

Smokers were included in eight investigations.[16,20,23,25,30–33] The proportion of smoking patients ranged from 9%[32] to 50%.[30,31] Four studies did not report on the patients' smoking habits.[22,24,29,34]

Table 4a Assessment of Risk of Bias for Included Controlled Clinical Studies with the Cochrane Risk of Bias Tool

Study, y	Random sequence generation	Allocation concealment	Blinding of particpants/ personnel	Blinding of outcome assessors	Incomplete outcome data	Selective reporting	Other bias	Summary assessment
Slot et al,[18] 2019	Unclear risk: No information provided.	Low risk: Patients were randomly allocated to one of the treatment groups by lot with the use of sealed envelopes.	Unclear risk: No information provided.	Low risk: Blinding not reported, but all measurements were performed by one examiner.	Low risk: Sample size calculation performed, patient dropouts and losses reported.	Low risk: Selective outcome reporting bias not detected.	Low risk: No other bias detected.	Unclear
Slot et al,[19] 2016	Unclear risk: No information provided.	Unclear risk: No information provided.	Unclear risk: No information provided.	Unclear risk: No information provided.	Low risk: Sample size calculation performed, patient dropouts and losses reported.	Low risk: Selective outcome reporting bias not detected.	Low risk: No other bias detected.	Unclear
Peñarrocha-Oltra et al,[21] 2014	High risk: No randomization performed.	High risk: Choice of procedure was determined at the time of surgery.	High risk: Choice of procedure was determined at the time of surgery.	Low risk: All measurements were collected by one trained clinician.	High risk: No sample size calculation was performed. No patient dropouts.	Low risk: Selective outcome reporting bias not detected.	Low risk: No other bias detected.	High
Stoker et al,[20] 2012	Unclear risk: No information provided.	Low risk: Through a computerized random allocation procedure, participants were allocated into 3 groups.	Unclear risk: No information provided.	Unclear risk: No information provided.	Low risk: Sample size calculation performed, patient dropouts and losses reported.	Low risk: Selective outcome reporting bias not detected.	Low risk: No other bias detected.	Unclear

Patients with a history of periodontitis were involved in four studies,[21,23,30,32] in which the proportion of periodontally compromised patients ranged from 52%[23,32] to 71%.[30] A study by Li et al involved only patients diagnosed with generalized aggressive periodontitis.[28] Periodontally compromised patients were excluded in two of the studies,[16,27] and the remaining articles did not provide information regarding patients' periodontal status.

Following placement of the prosthetic restoration, patients were enrolled into a regular maintenance program in half of the included studies.[16,18,21,22,25,27,29,32,33] The frequency of the maintenance appointments was indicated to be either every 6 months[16,21,25,29,32,33] or once a year.[18,27] Nine studies did not report on a maintenance program.[19,20,23,24,26,28,30,31,34]

Definitions of Peri-implant Diseases

Of the 18 selected studies, 4 used the case definitions for peri-implant mucositis and peri-implantitis suggested by the seventh[18,21,22] or eighth[19] European Workshops of Periodontology (EWOP; Tables 3a and 3b). Namely, peri-implantitis was defined as the presence of bleeding on probing (BOP), whereas the threshold value for marginal bone loss (MBL) of ≥ 2 mm, along with the presence of BOP or suppuration, was used to define peri-implantitis.

The definitions of peri-implant diseases varied within the rest of the studies, with different cut-off values used for the assessed clinical parameters. Particularly, peri-implant mucositis definitions were presented in six of the studies.[16,27,29–31,33] Three studies defined peri-implant mucositis as severe soft tissue inflammation in the absence of bone loss.[16,27,30] In two studies, the presence of bleeding was the criterion used for defining peri-implant mucositis,[29,31] and one definition included the presence of soft tissue inflammation with edema, rubor, and bleeding.[33]

The criteria defining peri-implantitis included presence of bone loss together with BOP and/or suppuration.[16,20,23–34] Bone loss thresholds of ≥ 2 mm,[23] ≥ 3 mm,[20] or annual bone loss > 0.2 mm[25] were specified in three investigations. For probing depth values, > 5 mm,[28] ≥ 6 mm,[20] or an increase in probing depth[29] were used for the definition of peri-implantitis.

Implant Characteristics

When the sample sizes of each study were combined, a total of 3,322 implants were included (Table 2). Of

Table 4b Assessment of Risk of Bias for Included Nonrandomized Clinical Studies with the ROBINS-I Tool

Study, y	Bias due to confounding	Bias in selection of participants into the study	Bias in classification of interventions	Bias due to deviations from intended interventions	Bias due to missing data
Windael et al,[23] 2018	Serious: No patient exclusion criteria applied.	Low	No comparison performed	Low	Low
Li et al,[28] 2017	Serious: Only a specific subgroup of patients was included.	Serious: Only patients with advanced generalized aggressive periodontitis were included.	No comparison performed	Low	Low
Zhang et al,[26] 2016	Moderate: Patient periodontal status not reported.	Low	No comparison performed	Low	Low
Krennmair et al,[27] 2016	Low	Low	High: Patients were assigned to the treatment groups at the time of surgery.	Low	Low
Cannizzaro et al, 2014,[17] 2018[16]	Moderate: Patient periodontal status not reported.	Low	No comparison performed	Low	Low
Meijer et al,[22] 2014	Serious: Patient-related factors were not evaluated.	High: Patient samples of 2 prospective studies were pooled.	No comparison performed	Low	Low
Lopes et al,[32] 2015	Serious: Patient-related factors were not evaluated.	Low	No comparison performed	Low	Moderate: Statistical analysis is unlikely to remove risk of bias arising from missing data.
Degidi et al,[33] 2013	Moderate: Patient periodontal status not reported.	Low	No comparison performed	Low	Serious: No information provided on statistical analysis to remove risk of bias arising from missing data.
Mertens et al,[25] 2012	Moderate: Patient periodontal status not reported.	Low	No comparison performed	Low	Low
Fischer and Steinberg,[24] 2012	Moderate: Patient periodontal status not reported. Information on the augmentation procedures is not clear.	Low	No comparison performed	Low	Moderate: Statistical analysis is unlikely to remove risk of bias arising from missing data.
Bergkvist et al,[29] 2009	Moderate: Patient periodontal status not reported.	Low	No comparison performed	Low	Moderate: Statistical analysis did not evaluate risk of bias arising from missing data.
Testori et al,[30] 2008	Moderate: Patient periodontal status not reported.	Low	Serious: Different patient sample numbers in control and test groups were evaluated.	Low	Moderate: Statistical analysis did not evaluate risk of bias arising from missing data.
Astrand et al,[34] 2004	Moderate: Patient periodontal status not reported.	Low	Low	Low	Low
Astrand et al,[31] 2000	Low	Low	Low	Low	Low

Bias in measurement of outcomes	Bias in selection of the reported results	Overall bias
Serious: No clear information.	Low	Serious
Serious: No information provided on who assessed the measurements.	Low	Serious
Serious: No information provided on who assessed the measurements.	Low	Serious
Low	Low	High
Low	Low	Moderate
Serious: No information provided on who assessed the measurements.	Low	Serious
Serious: No information provided on who assessed the clinical measurements. Only radiologic evaluation was reported to be performed by one outcome assessor.	Low	Serious
Serious No information provided on who assessed the clinical measurements.	Low	Serious
Low	Low	Moderate
Moderate: No information provided on who assessed the clinical measurements. Only radiologic evaluation was reported to be performed by the same examiner.	Low	Moderate
Moderate: No information provided on who assessed the clinical measurements and peri-implant diagnosis. Only radiologic evaluation was reported to be performed by a single oral radiologist.	Low	Moderate
Moderate: No information provided on who assessed the clinical measurements and biologic complications.	Serious: The outcome measure regarding biologic complications is subjective.	Serious
Moderate: No information provided on who assessed the clinical measurements and biologic complications.	Low	Moderate
Moderate: No clear information provided on who assessed the clinical measurements.	Low	Moderate

those, 2,280 implants (69%) were inserted in the maxilla, and the remaining 31% (1,042 implants) in the mandible. Immediate implant placement following tooth extraction was performed in one study[28]; two studies included both immediate and delayed implant placement[16,21]; and in the rest of the studies, implants were placed into the healed bone sites. The delayed implant placement was performed as a one-[23,29,30,32,33] or two-stage procedure.[18–21,24–27,31,34]

The mean number of implants inserted in the edentulous mandible ranged from two[16,20,22] to four to six implants.[23,27,28,32,33] Six to eight implants were placed in the edentulous maxilla in the majority of the studies.[21,24–26,29,30]

Single implant brands were used in 15 out of 18 investigations.[16,18–21,23–27,29–33] With regard to the bone augmentation procedures prior to or at the time of implant placement, in one of the included studies, bilateral sinus floor elevation with the lateral approach was performed 3 months prior to implant placement.[18] In two investigations, small dehiscence- or fenestration-type peri-implant defects during implant placement were filled with either a combination of autogenous bone + xenograft (Bio-Oss, Geistlich) + resorbable membrane,[19] or with autogenous bone or synthetic bone particles.[21] Two studies did not present data with regard to the presence or absence of bone augmentation procedures,[20,24] whereas in the remaining 13 studies, cases requiring bone augmentation procedures were excluded.[16,22,23,25–34]

Prosthetic Rehabilitation

In four of the studies, patients were provided implant-supported overdentures either in the maxilla[18,19] or in the mandible.[20,22] Except for one study in which full-arch prostheses were cemented,[26] patients received fixed, screw-retained, full-arch restorations.

In seven of the studies, inserted implants were immediately loaded.[16,23,28–30,32,33] One study employed immediate and conventional loading protocols,[21] and in the study by Zhang et al,[26] patients underwent early loading 6 weeks after implant insertion. In the remaining nine studies, implants were conventionally loaded after 2 to 3[18–20,22,27] or 6 to 7 months[25,31,34] following implant placement.

Prevalence of Peri-implant Mucositis and Peri-implantitis

Studies including only fully edentulous patients

A single study assessed the prevalence of peri-implant mucositis in edentulous patients restored with implant-supported overdentures at both the patient and implant levels.[22] After 5 years of implant function, peri-implant mucositis was detected in 51.9% of the patients, corresponding to 41.2% of the implants. Slightly greater values were noted at the 10-year follow-up (57% and 47%, respectively).[22]

Based on the data presented in seven investigations with a follow-up period of 5 to 11.26 years,[18–20,22,25,32,34] the peri-implantitis prevalence ranged from 1.5%[34] to 29.7%[22] of patients, and between 2.1%[32] and 20.3%[22] of implants. With respect to prosthetic restoration, 5%[18] to 20.3%[22] of implants and 4.5%[19] to 29.7%[22] of patients restored with implant-supported overdentures presented with peri-implantitis. Lower corresponding values were noted for the patients with implant-supported fixed restorations (implant level: 1.5%[31] to 8.7%[32]; patient level: 2.1%[25,32]).

When considering the studies that applied the disease definitions suggested by the previous EWOPs (sixth,[35] seventh,[3] and eighth[36]),[18,19,22] the peri-implantitis prevalence ranged from 4.5%[19] to 29.7%[22] of the patients after 5 and 10 years of follow-up, respectively.

Studies including fully edentulous and partially edentulous patients with opposing dentition

Six studies evaluated the prevalence of peri-implant mucositis in patients having at least one edentulous arch.[21,27,29–31,33] All patients in the aforementioned studies were restored with fixed full-arch restorations. Following 1 to 10 years of implant function, the peri-implant mucositis prevalence ranged from 0%[30] to 13.7%[21] of the patients and from 0%[30] to 12% of the implants.[29]

Based on the 10 studies with follow-up periods of 1 to 10 years ,[16,21,23,24,26,28–31,33] the prevalence of peri-implantitis ranged from 0%[21,30] to 25%[31] at the patient level and from 0%[21,30] to 7.2%[31] at the implant level.

According to the study using the definitions of the diseases suggested by the seventh EWOP,[3] peri-implant mucositis occurred in 13.7% of patients, which corresponded to 3.6% of implants.[21] None of the patients developed peri-implantitis during the 1-year follow-up period.[21]

DISCUSSION

The present systematic review aimed to evaluate the prevalence of peri-implant diseases (ie, peri-implant mucositis and peri-implantitis) in patients restored with implant-supported full-arch restorations. Seven investigations recruited only fully edentulous patients,[18–20,22,25,32,34] while 11 studies included patients having at least one edentulous arch.[16,21,23,25,26–31,33] Based on these findings, fully edentulous patients appeared to develop peri-implant mucositis (57% vs 0% to 13.7%) more often and have a higher range of peri-implantitis–affected implants compared to patients having at least one edentulous arch (2.1% to 20.3% and 0% to 7.2%, respectively). However, it should be pointed out that, based on the patient-level data, the occurrence of peri-implantitis was comparable between the two investigated groups (fully edentulous patients: 1.5% to 29.7%; patients having at least one edentulous arch: 0% to 25%).

In general, the reported prevalence values for peri-implant diseases in the included studies are in line with calculations presented in previously published systematic reviews.[36–38] Particularly, the reported overall mean prevalence of peri-implant mucositis ranged from 29.5% to 30.7% of the implants[37,38] and from 43% to 63.4% of the patients.[36–38] Accordingly, the mean prevalence of peri-implantitis varied between 9.2% and 9.6% of the implants[37,38] and between 18.8% and 22% of the patients.[36–38] As indicated by the authors, the high variation in the prevalence values among the studies might be attributed to the different case definitions used for peri-implant diseases.[36–38] For instance, the application of threshold values for probing depth ≥ 4 mm and bone loss ≥ 2 mm, respectively, resulted in a peri-implantitis prevalence of 20.4% of patients.[39] However, once thresholds of PD ≥ 6 mm and bone loss ≥ 3 mm were used, the prevalence of peri-implantitis decreased to 11.3%.[39] Likewise, bone loss thresholds of > 0.5 mm and > 3 mm resulted in the prevalence of peri-implantitis of 45% and 10.1% of the patients, respectively.[40]

Similarly, a major inconsistency among the studies with regard to the case definitions for peri-implant diseases was noted in the present analysis. Only 4 out of 18 investigations[15,18,21,22] used diagnostic criteria based on the guidelines established by the previous sixth, seventh, and eighth EWOPs,[3,35,41] while in the remaining papers, authors used their own definitions, with different threshold values applied for the clinical (PD, BOP) and radiographic (MBL) parameters. It is important to note that none of the studies assessed the changes in clinical and radiographic parameters compared to the baseline situation (ie, following prosthesis placement), but rather used their cutoff values. Therefore, due to the

varying definitions applied, the reported frequencies of the disease should be interpreted with caution.

A wide variety in definitions for peri-implant diseases has been highlighted in previous reports.[42,43] In congruence with the aforementioned systematic reviews, the apparent inconsistency in the definitions among the included studies might ultimately have an impact on the high variation of the reported prevalence of peri-implant diseases. Nevertheless, despite the inclusion of studies adhering to the case definitions of the eighth EWOP,[41] the estimated prevalence of peri-implantitis was found to be comparable to that reported in the aforementioned studies when all peri-implantitis definitions were pooled (18.5% of patients; range: 1% to 46%[44]; and 12.8% of implants; range: 0.2% to 63%.[44])

It was previously demonstrated that the composition of microbiota found at the peri-implant sulcus is related to the composition detected around the neighboring teeth.[6–8] Consequently, some authors have suggested that removal of the remaining periodontally diseased dentition reduces the risk of developing biologic peri-implant complications.[10,11] However, microbiologic analysis showed that full-mouth tooth extraction did not result in eradication but rather in a reduction of the periodontal pathogens.[45,46] Additionally, a prior systematic review evaluated clinical peri-implant tissue conditions among fully and partially edentulous patients.[47] The authors found that even though fully edentulous patients harbored more plaque and significantly higher bleeding indices at their implants than partially edentulous patients, no significant difference was observed in BOP, implant loss, or PDs between the two investigated patient groups.[47] Due to a lack of data, no comparison regarding differences in the prevalence of peri-implant mucositis and peri-implantitis between fully and partially edentulous patients was available.[47]

Currently, strong evidence points toward a correlation between peri-implantitis and a history of chronic periodontitis.[5] In particular, over the 10-year period, a higher incidence of peri-implantitis was detected in subjects with a history of periodontitis compared to nonperiodontitis patients (29% vs 6%, respectively).[48] Moreover, patients suffering from periodontitis yielded significantly higher odds of developing peri-implantitis after 5 (OR = 9)[49] and 9 to 14 years (OR = 5).[50] In this context, it should be noted that conflicting data failed to reveal an association between a history of periodontitis and an increased risk for developing peri-implantitis.[51] Similar MBL occurred at tooth and implant sites over a 3-year period, irrespective of the patients' periodontal status (ie, patients susceptible to periodontitis and patients without periodontitis).[52] In the current systematic review, due to considerable inconsistencies when reporting patients' periodontal status among the included studies, no comparison between the occurrence of peri-implant diseases and patients' periodontal health was possible.

With respect to prosthetic rehabilitation type, the results of the current analysis showed a higher frequency of peri-implantitis among edentulous patients restored with implant-supported overdentures than those restored with full-arch fixed restorations (4.5% to 29.7% and 1.5% to 8.7% of patients, respectively). In this context, it should be acknowledged that in the vast majority of cases, the overdentures were supported by bar-splinted dental implants.[18–20,22] One of the enrolled clinical investigations found a higher plaque accumulation around the bar-splinted implants than in the overdentures supported by two implants with ball attachments.[20] The aforementioned findings might be at least partially explained by the impeded oral hygiene of patients with overdentures supported by bar-splinted implants, which suggests that prosthesis design impacts the cleanability of the implants. Nevertheless, due to a lack of comparative studies, no conclusive remarks could be made regarding the impact of the prosthetic rehabilitation (ie, removable vs fixed) or of the retention mechanism of removable restorations (ie, bar-splinted implants, ball attachment, etc) on the frequency of peri-implant tissue disease in edentulous patients.

Further analysis of the findings of the present review revealed that implants showing bone loss of ≥ 0.5 mm during the first year of function were shown to be at a higher risk of developing peri-implantitis.[23] In particular, six out of eight implants showing progressive bone loss at the 10-year evaluation had peri-implant bone loss ≥ 0.5 mm during the first year of function.[23] In two of the studies, a majority of the patients diagnosed with peri-implantitis (four out of five[20] and five out of seven[31]) were reported to be smokers. Moreover, smokers were found to experience significantly more MBL than nonsmokers (P = .002).[20] The comparison of the clinical outcomes of the axially placed or tilted distal implants supporting mandibular full-arch fixed prostheses revealed no difference in the occurrence of biologic complications between the two implant groups (7.9% and 8.3% of the implants diagnosed with peri-implant mucositis, respectively).[27]

To the present authors' knowledge, this is the first systematic review evaluating the prevalence of peri-implant diseases in patients with full-arch implant-supported restorations. The observation showing that fully edentulous patients seem to have more implants affected by peri-implantitis corroborates the results of previous studies that assessed the prevalence of peri-implant diseases.[53–55] In particular, a positive correlation was found between peri-implant diseases and total edentulism (OR = 5.56[54]; OR = 16.1[53]).[55] As indicated by the authors, this higher risk of developing peri-implantitis might be explained by difficulty in performing adequate

oral hygiene and the fact that edentulous patients usually have a history of periodontitis and exhibit a higher inflammatory response to microbiota.[53]

According to the present analysis, factors such as bone loss of ≥ 0.5 mm during the first year of function[23] and smoking[20,31] were reported to be associated with the diagnosis of peri-implantitis. Findings regarding smoking are in accordance with previous systematic reviews, where a higher frequency of peri-implant diseases was recorded among patients who smoke.[37,38]

In the present systematic review, the majority of the patients were restored with conventionally loaded, maxillary, fixed full-arch restorations supported by implants inserted into the healed, nongrafted bone sites. However, taking into account the currently available data, it is not possible to assess whether the prosthetic design (removable or fixed), time of loading (immediate or conventional), implant location (maxilla or mandible), implant type, implant site grafting, and/or time of placement have any influence on the occurrence of peri-implant diseases in patients restored with full-arch implant-supported restorations.

CONCLUSIONS

Edentulous patients (fully edentulous or patients having at least one edentulous arch) restored with either fixed or removable restorations were frequently affected by peri-implant disease.

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37. Atieh MA, Alsabeeha NH, Faggion CM Jr, Duncan WJ. The frequency of peri-implant diseases: A systematic review and meta-analysis. J Periodontol 2013;84:1586–1598.
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39. Koldsland OC, Scheie AA, Aass AM. Prevalence of peri-implantitis related to severity of the disease with different degrees of bone loss. J Periodontol 2010;81:231–238.
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41. Sanz M, Chapple IL, Working Group 4 of the VIII European Workshop on Periodontology. Clinical research on peri-implant diseases: Consensus report of Working Group 4. J Clin Periodontol 2012;39(suppl 12):s202–s206.
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43. Peri-implant mucositis and peri-implantitis: A current understanding of their diagnoses and clinical implications. J Periodontol 2013;84:436–443.
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49. Costa FO, Takenaka-Martinez S, Cota LO, Ferreira SD, da Silva G, Costa JE. Peri-implant disease in subjects with and without preventive maintenance: A 5-year follow-up. J Clin Periodontol 2012;39:173–181.
50. Roos-Jansåker AM, Renvert H, Lindahl C, Renvert S. Nine- to fourteen-year follow-up of implant treatment. Part III: Factors associated with peri-implant lesions. J Clin Periodontol 2006;33:296–301.
51. Rokn A, Aslroosta H, Akbari S, Najafi H, Zayeri F, Hashemi K. Prevalence of peri-implantitis in patients not participating in well-designed supportive periodontal treatments: A cross-sectional study. Clin Oral Implants Res 2017;28:314–319.
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54. Marrone A, Lasserre J, Bercy P, Brecx MC. Prevalence and risk factors for peri-implant disease in Belgian adults. Clin Oral Implants Res 2013;24:934–940.
55. Rodrigo D, Sanz-Sánchez I, Figuero E, et al. Prevalence and risk indicators of peri-implant diseases in Spain. J Clin Periodontol 2018;45:1510–1520.

APPENDIX 1 Studies Excluded After Full-Text Reading (Electronic [n = 51] and Hand [n = 5] Searches)

Did Not Evaluate Prevalence of Peri-implant Diseases

PubMed Search

1. Primo BT, Mezzari LM, da Fontoura Frasca LC, Linderman R, Rivaldo EG. Clinical and radiographic assessment of three-implant–supported fixed prosthesis rehabilitation of the edentulous mandible: Immediate versus delayed loading. Int J Oral Maxillofac Implants 2018;33:653–660.
2. Cannizzaro G, Gastaldi G, Gherlone E, et al. Two or three machined vs roughened surface dental implants loaded immediately supporting total fixed prostheses: 1-year results from a randomised controlled trial. Eur J Oral Implantol 2017;10:279–291.
3. Giannakopoulos NN, Ariaans K, Eberhard L, Klotz AL, Oh K, Kappel S. Immediate and delayed loading of two-piece reduced-diameter implants with locator-analog attachments in edentulous mandibles: One-year results from a randomized clinical trial examining clinical outcome and patient expectation. Clin Implant Dent Relat Res 2017;19:643–653.
4. Ayna M, Gülses A, Acil A. A comparative study on 7-year results of "All-on-Four" immediate-function concept for completely edentulous mandibles: Metal-ceramic vs. bar-retained superstructures. Odontology 2018;106:73–82.
5. Elsyad MA, Shaheen NH, Ashmawy TM. Long-term clinical and prosthetic outcomes of soft liner and clip attachments for bar/implant overdentures: A randomised controlled clinical trial. J Oral Rehabil 2017;44:472–480.
6. Faria PE, Masalskas B, Heyden A, Rasmusson L, Salata LA. Immediate loading of implants in the edentulous mandible: A multicentre study. Oral Maxillofac Surg 2016;20:385–390.
7. Elsyad MA, Alokda MM, Gebreel AA, Hammouda NI, Habib AA. Effect of two designs of implant-supported overdentures on peri-implant and posterior mandibular bone resorptions: A 5-year prospective radiographic study. Clin Oral Implants Res 2017;28:e184–e192.
8. Meloni SM, Tallarico M, Pisano M, Xhanari E, Canullo L. Immediate loading of fixed complete denture prosthesis supported by 4-8 implants placed using guided surgery: A 5-year prospective study on 66 patients with 356 implants. Clin Implant Dent Relat Res 2017;19:195–206.
9. Urban IA, Monje A, Lozada JL, Wang HL. Long-term evaluation of peri-implant bone level after reconstruction of severely atrophic edentulous maxilla via vertical and horizontal guided bone regeneration in combination with sinus augmentation: A case series with 1 to 15 years of loading. Clin Implant Dent Relat Res 2017;19:46–55.
10. Gomes JA, Sartori IAM, Able FB, de Oliveira Silva TS, do Nascimento C. Microbiological and clinical outcomes of fixed complete-arch mandibular prostheses supported by immediate implants in individuals with history of chronic periodontitis. Clin Oral Implants Res 2017;28:734–741.
11. Pozzi A, Tallarico M, Moy PK. Four-implant overdenture fully supported by a CAD-CAM titanium bar: A single-cohort prospective 1-year preliminary study. Prosthet Dent 2016;116:516–523.
12. Schincaglia GP, Rubin S, Thacker S, Dhingra A, Trombelli L, Ioannidou E. Marginal bone response around immediate- and delayed-loading implants supporting a Locator-retained mandibular overdenture: A randomized controlled study. Int J Oral Maxillofac Implants 2016;31:448–458.
13. Esposito M, Felice P, Barausse C, Pistilli R, Grandi G, Simion M. Immediately loaded machined versus rough surface dental implants in edentulous jaws: One-year postloading results of a pilot randomised controlled trial. Eur J Oral Implantol 2015;8:387–396.
14. Tallarico M, Meloni SM, Canullo L, Caneva M, Polizzi G. Five-year results of a randomized controlled trial comparing patients rehabilitated with immediately loaded maxillary cross-arch fixed dental prosthesis supported by four or six implants placed using guided surgery. Clin Implant Dent Relat Res 2016;18:965–972.
15. Pozzi A, Tallarico M, Moy PK. Immediate loading with a novel implant featured by variable-threaded geometry, internal conical connection and platform shifting: Three-year results from a prospective cohort study. Eur J Oral Implantol 2015;8:51–63.
16. Zou D, Wu Y, Huang W, et al. A 3-year prospective clinical study of telescopic crown, bar, and locator attachments for removable four implant-supported maxillary overdentures. Int J Prosthodont 2013;26:566–573.
17. Friberg B, Jemt T. Rehabilitation of edentulous mandibles by means of osseointegrated implants: A 5-year follow-up study on one or two-stage surgery, number of implants, implant surfaces, and age at surgery. Clin Implant Dent Relat Res 2015;17:413–424.
18. Frisch E, Ziebolz D, Ratka-Krüger P, Rinke S. Double crown-retained maxillary overdentures: 5-year follow-up. Clin Implant Dent Relat Res 2015;17:22–31.
19. Roe P, Kan JY, Rungcharassaeng K, Lozada JL. Immediate loading of unsplinted implants in the anterior mandible for overdentures: 3-year results. Int J Oral Maxillofac Implants 2011;26:1296–1302.
20. Fischer K, Stenberg T. Prospective 10-year cohort study based on a randomized, controlled trial (RCT) on implant-supported full-arch maxillary prostheses. Part II: Prosthetic outcomes and maintenance. Clin Implant Dent Relat Res 2013;15:498–508.
21. Pieri F, Aldini NN, Fini M, Marchetti C, Corinaldesi G. Immediate fixed implant rehabilitation of the atrophic edentulous maxilla after bilateral sinus floor augmentation: A 12-month pilot study. Clin Implant Dent Relat Res 2012;14(suppl 1):e67–e82.
22. Krennmair G, Seemann R, Weinländer M, Piehslinger E. Comparison of ball and telescopic crown attachments in implant-retained mandibular overdentures: A 5-year prospective study. Int J Oral Maxillofac Implants 2011;26:598–606.
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24. Akoglu B, Ucankale M, Ozkan Y, Kulak-Ozkan Y. Five-year treatment outcomes with three brands of implants supporting mandibular overdentures. Int J Oral Maxillofac Implants 2011;26:188–194.
25. Mangano C, Mangano F, Shibli JA, Ricci M, Sammons RL, Figliuzzi M. Morse taper connection implants supporting "planned" maxillary and mandibular bar-retained overdentures: A 5-year prospective multicenter study. Clin Oral Implants Res 2011;22:1117–1124.
26. Degidi M, Nardi D, Piattelli A. Immediate loading of the edentulous maxilla with a definitive restoration supported by an intraorally welded titanium bar and tilted implants. Int J Oral Maxillofac Implants 2010;25:1175–1182.
27. Gallucci GO, Doughtie CB, Hwang JW, Fiorellini JP, Weber HP. Five-year results of fixed implant-supported rehabilitations with distal cantilevers for the edentulous mandible. Clin Oral Implants Res 2009;20:601–607.
28. Marzola R, Scotti R, Fazi G, Schincaglia GP. Immediate loading of two implants supporting a ball attachment-retained mandibular overdenture: A prospective clinical study. Clin Implant Dent Relat Res 2007;9:136–143.
29. Ortorp A, Jemt T. Clinical experiences with laser-welded titanium frameworks supported by implants in the edentulous mandible: A 10-year follow-up study. Clin Implant Dent Relat Res 2006;8:198–209.
30. Jemt T, Johansson J. Implant treatment in the edentulous maxillae: A 15-year follow-up study on 76 consecutive patients provided with fixed prostheses. Clin Implant Dent Relat Res 2006;8:61–69.
31. Krennmair G, Weinländer M, Krainhöfner M, Piehslinger E. Implant-supported mandibular overdentures retained with ball or telescopic crown attachments: A 3-year prospective study. Int J Prosthodont 2006;19:164–170.
32. Farzad P, Andersson L, Gunnarsson S, Sharma P. Implant stability, tissue conditions, and patient self-evaluation after treatment with osseointegrated implants in the posterior mandible. Clin Implant Dent Relat Res 2004;6:24–32.
33. Ekelund JA, Lindquist LW, Carlsson GE, Jemt T. Implant treatment in the edentulous mandible: A prospective study on Brånemark system implants over more than 20 years. Int J Prosthodont 2003;16:602–608.
34. Mau J, Behneke A, Behneke N, et al. Randomized multicenter comparison of 2 IMZ and 4 TPS screw implants supporting bar-retained overdentures in 425 edentulous mandibles. Int J Oral Maxillofac Implants 2003;18:835–847.
35. Yi SW, Ericsson I, Kim CK, Carlsson GE, Nilner K. Implant-supported fixed prostheses for the rehabilitation of periodontally compromised dentitions: A 3-year prospective clinical study. Clin Implant Dent Relat Res 2001;3:125–134.
36. Inan O, Aykent F, Alptekin N. Implant-supported overdenture therapy: A 3- to 8-year prospective study. Implant Dent 2000;9:369–373.
37. Zitzmann NU, Marinello CP. Treatment outcomes of fixed or removable implant-supported prostheses in the edentulous maxilla. Part II: Clinical findings. J Prosthet Dent 2000;83:434–442.
38. Cooper LF, Moriarty JD, Guckes AD, et al. Five-year prospective evaluation of mandibular overdentures retained by two microthreaded, TiOblast nonsplinted implants and retentive ball anchors. Int J Oral Maxillofac Implants 2008;23:696–704.

Hand Search

1. Collaert B, De Bruyn H. Immediate functional loading of TiOblast dental implants in full-arch edentulous maxillae: A 3-year prospective study. Clin Oral Implants Res 2008;19:1254–1260.
2. Slot W, Raghoebar GM, Vissink A, Meijer HJA. A comparison between 4 and 6 implants in the maxillary posterior region to support an overdenture; 1-year results from a randomized controlled trial. Clin Oral Implants Res 2014;25:560–566.
3. Tealdo T, Menini M, Bevilacqua M, et al. Immediate versus delayed loading of dental implants in edentulous patients´ maxillae: A 6-year prospective study. Int J Prosthodont 2014;27:207–214.

Retrospective Studies

PubMed Search

1. Cercadillo-Ibarguren I, Sánchez-Torres A, Figueiredo R, Schwarz F, Gay-Escoda C, Valmaseda-Castellón E. Immediately loaded implant-supported full-arches: Peri-implant status after 1–9 years in a private practice. J Dent 2017;67:72–76.
2. Giordano F, Esposito M. Immediate loading of fixed prostheses in fully edentulous jaws—1-year follow-up from a single-cohort retrospective study. Eur J Oral Implantol 2017;10:339–348.
3. Menini M, Setti P, Pera P, Pera F, Pesce P. Peri-implant tissue health and bone resorption in patients with immediately loaded, implant-supported, full-arch prostheses. Int J Prosthodont 2018;31:327–333.

Hand Search

1. Passoni BB, Dalaga HR, Schuldt Filho G, et al. Does the number of implants have any relation with peri-implant disease? J Appl Oral Sci 2014;22:403–408.

Case Series Studies

PubMed Search

2. Martens F, Vandeweghe S, Browaeys H, De Bruyn H. Peri-implant outcome of immediately loaded implants with a full-arch implant fixed denture: A 5-year prospective case series. Int J Periodontics Restorative Dent 2014;34:189–197.

No Clear Definition of Peri-implant Diseases

PubMed Search

1. Acham S, Rugani P, Truschnegg A, Wildburger A, Wegscheider WA, Jakse N. Immediate loading of four interforaminal implants supporting a locator-retained mandibular overdenture in the elderly. Results of a 3-year randomized, controlled, prospective clinical study. Clin Implant Dent Relat Res 2017;19:895–900.
2. Turkyilmaz I, Tozum TF, Fuhrmann DM, Tumer C. Seven-year follow-up results of TiUnite implants supporting mandibular overdentures: Early versus delayed loading. Clin Implant Dent Relat Res 2012;14(suppl 1):e83–e90.
3. Ueda T, Kremer U, Katsoulis J, Mericske-Stern R. Long-term results of mandibular implants supporting an overdenture: Implant survival, failures, and crestal bone level changes. Int J Oral Maxillofac Implants 2011;26:365–372.
4. Schwarz S, Gabbert O, Hassel AJ, Schmitter M, Séché C, Rammelsberg P. Early loading of implants with fixed dental prostheses in edentulous mandibles: 4.5-year clinical results from a prospective study. Clin Oral Implants Res 2010;21:284–289.
5. Astrand P, Ahlqvist J, Gunne J, Nilson H. Implant treatment of patients with edentulous jaws: A 20-year follow-up. Clin Implant Dent Relat Res 2008;10:207–217.
6. Cannizzaro G, Leone M, Esposito M. Immediate functional loading of implants placed with flapless surgery in the edentulous maxilla: 1-year follow-up of a single cohort study. Int J Oral Maxillofac Implants 2007;22:87–95.
7. Hellem S, Karlsson U, Almfeldt I, Brunell G, Hamp SE, Astrand P. Non-submerged implants in the treatment of the edentulous lower jaw: A 5-year prospective longitudinal study of ITI hollow screws. Clin Implant Dent Relat Res 2001;3:20–29.

Hand Search

1. Malo P, de Araujo Nobre M, Lopes A. The use of computer-guided flapless implant surgery and four implants placed in immediate function to support a fixed denture: Preliminary results after a mean follow-up period of thirteen months. J Prosthet Dent 2007;97(6 suppl):s26–s34.

Did Not Report on Prevalence of Peri-implant Diseases

PubMed Search

1. Cannizzaro G, Felice P, Gherlone E, et al. Immediate loading of two (fixed-on-2) vs four (fixed-on-4) implants placed with a flapless technique supporting mandibular cross-arch fixed prostheses: 3-year results from a pilot randomised controlled trial. Eur J Oral Implantol 2017;10:133–145.
2. Cannizzaro G, Loi I, Viola P, et al. Immediate loading of two (fixed-on-2) versus three (fixed-on-3) implants placed flapless supporting cross-arch fixed prostheses: One-year results from a randomised controlled trial. Eur J Oral Implantol 2016;9 suppl 1(2):s143–s153.

Follow-up Period < 1 y

PubMed Search

1. Cannizzaro G, Felice P, Soardi E, Ferri V, Leone M, Esposito M. Immediate loading of 2 (all-on-2) versus 4 (all-on-4) implants placed with a flapless technique supporting mandibular cross-arch fixed prostheses: Preliminary results from a pilot randomised controlled trial. Eur J Oral Implantol 2011;4:205–217.