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Long-term peri-implant health and disease in patients without or with mild periodontitis as compared to severe periodontitis.

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Long-term peri-implant health and disease in patients without or with mild periodontitis as compared to severe periodontitis.

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ABSTRACT

AIM: The aim of this systematic review was to determine if there is a difference in peri-implant health and disease between patients with no or mild periodontitis and patients with severe periodontitis, in terms of prevalence/incidence of peri-implant health, peri-implant mucositis, peri-implantitis and implant loss, as shown in observational studies and randomized controlled trials (RCTs) with ≥10 years follow-up time.

MATERIALS AND METHODS: RCTs and observational studies fulfilling the criteria to answer the PICOS question were included. A single search was performed in four electronic databases. Two review authors independently screened studies based on title- and abstract, whereafter full-text screening was performed. The third author was consulted in case of disagreement. Peri-implant health, mucositis, peri-implantitis and implant loss were considered the outcomes of critical importance.

RESULTS: After removing duplicates, 1005 articles were screened for title and abstract, out of which 970 were excluded. An additional 32 studies were excluded during full-text screening, and ultimately three studies were included. Peri-implant health and mucositis was scarcely reported in the studies. Peri-implantitis was reported from 5.1% to 28.6% at implant level, with a three- to five-fold higher prevalence in periodontitis patients. Implant loss was reported from 2.2% to 9.5%, with a threefold higher rate in periodontitis patients.

CONCLUSIONS: The included studies suggested that patients with severe periodontitis were at higher risk of peri-implantitis and implant loss as compared to patients without or with mild periodontitis.

CONTENTS

INTRODUCTION

Dental implant rehabilitation is an alternative for tooth replacement following tooth loss or missing teeth. It involves a surgical procedure for placement of the implant and the final replacement is usually provided a few months after the surgical placement. This contrasts tooth replacement with removable dentures and fixed bridges, which may be delivered in shorter time. Implant-supported rehabilitations surpasses the need for tooth preparation, but as for any dental rehabilitation, it requires long-term maintenance to reduce the risk of complications (Costa et al., 2012).

Dental implant rehabilitation is increasing, and a study published in 2018 by Elani and co-workers on the prevalence of implants in the USA showed a 5% prevalence. The same study predicted the prevalence in 2026 to range from 5.7% to 23%.

Dental implant rehabilitation may be a reliable long-term treatment. A recent meta-analysis reported an implant survival rate after 10 years at 96% at implant level (Howe, 2019). A pilot study reporting on satisfaction of implant-supported crowns and fixed dental prostheses showed that patients with both solutions were equally satisfied with both, in terms of function and aesthetics (Thieu et al., 2023).

Even though dental implant rehabilitations in general offer a high survival rate and are increasingly used, biological and/or technical complications may occur. Technical complications other than implant fractures usually do not lead to implant loss, but an increased number of repairs may lead to extra chair-time and costs, which in turn may impact on patient satisfaction and quality of life (Mauland et al., 2024). Technical complications are related to the implant or the suprastructure itself, including fractures, poor fit and prosthetic contours and unusual wear (Papaspyridakos et al., 2018), whereas biological complications are often host-dependent and occur in the peri-implant soft tissues. Biological complications may include failure of osseointegration, allergic reactions, peri-implant diseases or hypertrophy (Papaspyridakos et al., 2018). Peri-implant diseases include peri-implant mucositis and peri-implantitis. The former is characterized by inflammation in the mucosa surrounding dental implants without any loss of implant-supporting bone (Berglundh et al., 2018), but may develop into peri-implantitis if untreated. Peri-implantitis includes bone loss as well as inflammation in the peri-implant mucosa (Berglundh et al., 2018).

The prevalence of peri-implant diseases has been studied for many years and depends on disease definition and the demographics of the population. Koldsland and co-workers (2010) reported a prevalence of peri-implant mucositis at 20.4% at patient level and 11.4% at implant level, when bone loss ≥2 mm and PPD ≥ 4 mm was used as threshold. A meta-analysis by Derks & Tomasi (2016) reported a 43% prevalence of peri-implant mucositis and 22% for peri-implantitis at patient level. Kordbacheh and co-workers (2019) did a 2-year follow-up study and reported peri-implant mucositis at 34% on patient level and 21% on implant level. According to the available data, it has been demonstrated that peri-implant diseases are common and should be taken into account when considering dental-implant treatment.

Periodontitis is a multifactorial inflammatory disease caused by dental plaque, which affects the soft tissues and leads to loss of attachment and can eventually lead to tooth loss. Patients with poor plaque control or lack of compliance to supportive therapy have an increased risk of developing peri-implant mucositis (Berglundh et al., 2022) and peri-implantitis (Berglundh et al., 2022; Costa et al., 2012). In parallel to periodontitis, poor plaque control is a risk factor for developing peri-implantitis (Berglundh et al., 2022; Roccuzzo et al., 2010; Koldsland et al., 2011; Roos-Jansåker et al., 2006). Despite this, periodontitis patients can still be considered for rehabilitation with dental implants provided there is no active inflammation, and sufficient hygiene and supportive treatment is ensured. It is therefore important to assess the periodontal status when considering dental implant treatment. However, there is limited knowledge on how periodontal disease may impact on peri-implant health or disease in the long-term. Therefore, the aim of this study was to assess if there is a difference in peri-implant health and disease between patients with no or mild periodontitis as compared to patients with severe periodontitis.

To address this research question, the following PICOS-question was used to undertake a systematic review. In human subjects with dental implants (P), is there a difference in peri-implant health or disease in patients with no/mild periodontitis (stage 0, I,II or CAL <5mm) (I) as compared to patients with severe periodontitis (stage III, IV or CAL ≥5mm) (C), in terms of prevalence/incidence of peri-implant health, peri-implant mucositis, peri-implantitis and implant loss (O), as shown in observational studies and randomized controlled trials (RCTs) with at least 10-year follow-up (S)?

MATERIAL & METHODS

Prior to the literature search, a detailed protocol was made and agreed upon by the authors.

Focused question

In human subjects with dental implants (P), is peri-implant health different in patients with no/mild periodontitis (stage 0, I,II or CAL <5mm) (I) as compared to patients with severe periodontitis (stage III, IV or >5mm) (C), in terms of prevalence of health, peri-implant mucositis, peri-implantitis and implant loss (O), as shown in observational studies and RCTs with ≥ 10-year follow-up (S)?

Literature search and study design

A search was made until December 20th 2022, and screening/selection was completed March 5th 2023 in four different databases; Medline, Embase, Cochrane and Scopus. The search strategy included the following keywords; "dental implant* AND periodontitis AND (peri implant health OR peri implant mucositis OR peri implantitis OR implant loss). The identified studies were uploaded in Covidence (www.covidence.org/) (Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia) and two reviewers (Bakstad & Kramer) independently performed title- and abstract-screening and thereafter full-text screening. The third author for consulted in case of disagreement. The reason for full-text exclusion was recorded, and the inter-reviewer agreement (percentage of agreement and kappa correlation coefficient) of the screening and full-text analysis was determined.

Eligibility criteria

1. Observational studies or randomized controlled trials (RCTs) reporting on peri-implant health and/or peri-implant mucositis and/or peri-implantitis and/or implant loss in human subjects with mild/no periodontitis and patients with periodontitis.
2. Studies including human subjects with periodontitis defined as either stage III, IV or CAL ≥ 5mm, and without periodontitis or mild periodontitis (stage 0, I, II or CAL <5mm) who have dental implants.
3. Studies including at least 50 patients.
4. Only studies published in English or Norwegian.
5. Only peer-reviewed studies.

6. Only studies published after 1965.
7. Studies with ≥ 10-year follow-up after implant loading.
8. “Peri-implantitis” defined as inflammation in the peri-implant mucosa, as well as ≥3 mm bone loss if assessed cross-sectionally or progressive bone loss in prospectice studies.
9. “Peri-implant mucositis” defined as inflammation (e.g. swelling and redness) and bleeding on probing (BoP) and/or suppuration on probing (SoP) in peri-implant mucosa, without bone loss.
10. “Peri-implant health” defined as absence of inflammation and bone loss.

RESULTS

Search results, screening and selection

A total of (n=1352) studies were identified from the four different databases. Following removal of duplicates, (n=1005) were imported to Covidence for title and abstract screening. Of these, 970 were excluded after abstract- and title-screening (agreement = 95.3%; k = 0.47). Disagreements were resolved with the last author. In the full-text screening an additional 32 articles were excluded (Table 1). Ultimately, three articles were included in this systematic review (Table 2) (Dierens et al., 2012; Karoussis et al., 2003; Windael et al., 2021). A flow-chart of the screening process is provided in Figure 1.

Characteristics of the included studies

Table 2 provides details of methodology and participants of the included studies. All three studies were prospective (Windael et al., 2021; Dierens et al., 2012; Karoussis et al., 2003).

In Dierens and co-workers (2012), no participants presented periodontitis at implant placement, and agenesia and trauma were the main reasons for tooth loss. The population's mean age was only 23.9 years at the time of implant placement. After a mean follow-up time of 18.4 years, only one patient out of 50 was considered a periodontitis patient without further specification. All patients were rehabilitated with single turned Brånemark System ® external hex implants (Nobel Biocare AB, Göteborg, Sweden).

In Karoussis and co-workers (2003), 53 patients of which 45 had no history of periodontitis, were followed for 10 years. In this study, all implants were hollow screw ITI® (Institute Straumann AG, Waldenburg, Switzerland).

In Windael and co-workers (2021), 407 patients were examined 10-14 years after implant rehabilitation. 200 of these patients were classified as patients with severe periodontitis. All implants were placed by the same surgeon and were Osseospeed® implants (Astra Tech AB, Molndal, Sweden).

Peri-implant health

In only one study it was possible to deduct the number of implants without BoP and bone loss <2.7 mm, but this study consisted of young non-periodontitis patients (Dierens et al. 2012) (Table 3). In the study, 11 out of the remaining 59 (18.6%) implants demonstrated peri-implant health.

Peri-implant mucositis

Two of the studies reported on peri-implant mucositis, but in Windael and co-workers (2021) it was not discriminated between mucositis in patients with or without periodontitis.

In Dierens and co-workers (2012), a prevalence of peri-implant mucositis on implant level of 76.3% was found, but this was in patients without periodontitis only (Table 4).

Peri-implantitis

All studies assessed peri-implantitis (Table 5). None of the studies reported on patient level, and the data was exclusively reported on implant level.

Dierens and co-workers (2012) found peri-implantitis in 3 of 59 (5.1%) of all implants. None were periodontitis patients at implant placement and only one was considered a periodontitis patient at the final examination. There was no information on how many implants this patient had, nor if this patient had peri-implantitis or not.

Karoussis and co-workers (2003) found that 5 of 91 (5.5%) implants in patients without/mild periodontitis and 6 of 21 (28.6%) implants in patients with severe periodontitis exhibited peri-implantitis. The latter group presented a five-fold higher incidence of peri-implantitis.

Windael and co-workers (2021) reported peri-implantitis in 24 of 455 implants (5.3%) in patients with no/mild periodontitis, compared to 140 of 897 (15.6%) implants in patients with severe periodontitis. The differences in peri-implantitis incidence in these groups were not statistically significant. However, it was found that non-smokers with less than 0.5 mm early bone loss, with or without a history of periodontitis, exhibited a statistically significant lower likelihood of developing peri-implantitis, compared to smokers with history of periodontitis and early bone loss.

Implant loss

All studies reported on implant loss (Table 6). Dierens and co-workers (2012) included assessment at both implant- and patient level, whereas Karoussis and co-workers (2003) and Windael and co-workers (2021) only assessed implant loss on implant level.

In the study by Dierens and co-workers (2012),, 3 of 62 (4.8%) implants were lost. At patient level, only 2 of 50 (4%) patients lost one implant or more.

In the study conducted by Karoussis and co-workers (2003), implant loss was observed in 3 of 91 implants (3.5%) in the group of patients without or with mild periodontitis, while in the group of patients with severe periodontitis, 2 of 21 implants (9.5%) were lost. However, this difference was not statistically significant.

Windael and co-workers' study (2021) included a larger number of implants. In their study, 10 of 455 (2.2%) implants were lost in the group of patients without/mild periodontitis. In the group of patients with severe periodontitis, the number of lost implants was 56 of 897 (6.2%).

DISCUSSION

The studies included reported limited results for peri-implant health. None of the included studies reported on peri-implant mucositis in relation to periodontitis. Patients with severe periodontitis consistently presented a higher risk of peri-implantitis and implant loss as compared to patients without/mild periodontitis.

The findings of this systematic review suggests that dental implants in patients with severe periodontitis have a higher risk of peri-implant disease and implant loss than patients without/mild periodontitis. These are important findings for several reasons. Awareness of the risk of peri-implant disease and implant loss may help clinicians and patients in considering if dental implant rehabilitation is the best treatment alternative and what to expect in terms of success and survival of the implant. This present review only included studies with at least ten years follow-up time. This considerable follow-up time provides long-term data on implant survival and peri-implant diseases.

A similar systematic review on this topic was reported by Ong and co-workers (2008). The study concluded that there is limited evidence concerning implant loss and complications related to implants in patients with periodontitis. This present review differed from the previous systematic review in terms of eligibility criteria. Ong and co-workers (2008) included studies with a lower number of patients and at least 6-month follow-up. Ong and co-workers (2008) included studies covering various types and severities of periodontitis, alongside different treatment approaches and their effectiveness. The review compared patients without clinical or radiographic sign of periodontitis, whereas this review compared patients based on the inclusion criteria: without or with mild periodontitis. Accordingly, the search in Ong and co-workers (2008) was wider and included studies that reported on implant survival and success, including studies that did not necessarily have periodontitis as the main focus of the study.

Ramanauskaite and co-workers (2014) also performed a systematic review on this topic, which included studies with at least five years follow-up time. All 14 included studies reported inferior implant survival rates in periodontitis patients as compared to non-periodontitis patients. However, only three of the included studies reported a statistically significant difference. The meta-analysis did not show a statistically significant difference in

implant survival rates between periodontitis patients and non-periodontitis patients. In the same review, seven studies reported on peri-implantitis (Ramanauskaite et al., 2014). The meta-analysis found that six included studies collectively demonstrated a significantly higher risk of peri-implantitis in periodontitis patients as compared to non-periodontitis patients. Ramanauskaite and co-workers (2014) included studies with different definitions of “peri-implantitis", “chronic periodontitis” and “periodontally healthy”. Therefore, a comparison between this meta-analysis and the present is not feasible, also considering the difference in the follow-up time inclusion criteria. In 2018, Schwarz and co-workers published a review on peri-implantitis. The review confirmed the higher risk of peri-implantitis in patients with a history of periodontitis. These findings were reported despite including studies with shorter follow-up times.

This systematic review including only studies with a long follow-up suggests that patients with periodontitis have a higher risk of peri-implant diseases and implant loss. However, alternative explanations for these findings must be considered. Periodontitis and peri-implant disease have similar risk factors, indicators, and pathogenesis. Poor plaque control and lack of compliance to supportive therapy are risk factors for both periodontitis and peri-implant disease (Schwarz et al., 2018). The individual studies did not always consider confounding factors like plaque or smoking, and there may also be other confounders. Smoking may be a confounding factor in developing peri-implant disease and implant loss and is a well-known risk factor for periodontitis. Karoussis and co-workers (2003) divided both groups of periodontitis and non-periodontitis patients into non-smokers and smokers, and analysed the prevalence of success, biological complications, and survival. However, their analysis showed no statistically significant difference between smokers and non-smokers. Nonetheless, smokers exhibited a lower tendency towards implant survival. It is worth noting the study’s small sample size, and its possible impact of the results. Windael and co-workers (2021) considered smoking together with early bone loss as a predictor for implant loss. They reported a significantly lower risk of developing peri-implantitis in non-smokers with ≤ 0.5 mm early bone loss with or without a history of periodontitis, when compared to the group of smokers, with early bone loss >0.5mm and a history of periodontitis. Importantly, the risk of smoking for peri-implantitis is equivocal (Schwarz et al., 2018; Bain & Moy, 1993; Wilson & Nunn, 1999; Ong et al., 2008). Since smoking may be a confounding factor, it may potentially affect the prevalence and incidence of peri-implant disease and implant loss in both patients with and without periodontitis.

Systemic diseases, such as diabetes, may also be an alternative explanation to peri-implant diseases and/or implant loss. A number of studies have confirmed the link between periodontitis and diabetes (Lindhe et al., 2008). However, there is no consensus on the link between peri-implantitis and diabetes to date. Regarding other systemic diseases, studies are limited (Schwarz et al., 2018). The studies included in this systematic review did not particularly report on systemic diseases.

Different implant systems present different surface macro- and micro-structures that render unique properties. These differences may affect the risk of technical and biological complications (De Bruyn et al., 2017; Polizzi et al., 2013). Each of the three included studies employed different implant systems, but within each study, the same implant system was consistently used for all patients. Karoussis and co-workers (2003) used the hollow screw ITI® Dental Implant System (Institute Straumann AG, Waldenburg, Switzerland). This type of implant is characterized by hollow perforations which allow for bone ingrowth (Weber et al., 2002). The SLA®-surface is sandblasted with large grit for macro-roughness, then acid-etched for micro-roughness (Nicolas-Silvente et al., 2020). Windael and co-workers (2021) used Osseospeed ® implants (Astra Tech AB, Molndal, Sweden). The surface of these implants is sandblasted with titanium oxide, followed by an incorporation of fluoride (Nicolas-Silvente et al., 2020). Dierens et al. (2012) used single turned standard external hex Brånemark ® implants (Nobel Biocare AB, Göteborg, Sweden). These implants are characterized by a polished titanium oxide surface (Nicolas-Silvente et al., 2020). The different implant surface characteristics influence osseointegration but may also present different risk of peri-implantitis. Finally, in studies with follow-up time ≥10 years, it is inevitable that patients are lost to follow-up. Whether these patients present more or less implant loss and peri-implant diseases is not known.

There is a lot of research on implants and their complications. In this systematic review, numerous studies were excluded, and many due to a follow-up time of less than ten years. Studies with longer follow-up times mirror the long-term outcomes of implant treatment. Onset of peri-implant diseases may vary, and a higher prevalence of disease is expected in studies with longer follow-up periods (Derks & Tomasi, 2016). The disadvantage with the exclusion of studies with less than ten-year follow-up is of course that only very few studies were ultimately included, and a lot of important data may be excluded. This analysis included

three studies only, which collectively may not reflect of reality. By including more studies, reliability increases. Therefore, more long-term research is needed in the follow-up of dental implant rehabilitation.

In this analysis, patients were categorized in two groups: severe or without/mild periodontitis. The cut-off of severe periodontitis was defined to be periodontitis stage 3, 4 or CAL ≥ 5 mm. Accordingly, patients with mild periodontitis (stage 1,2 or CAL < 5mm) were in the same group as non-periodontitis patients. This cut-off can be criticized, as there may be a possibility of increased prevalence of peri-implant disease and loss in the non-periodontitis/mild periodontitis patient group as well (Ong et al., 2008). In the study by Karoussis and co-workers (2023) there was limited information of what comprised "history of periodontitis"-patients, but it was stated that these patients received implants to replace teeth lost due to periodontitis, and therefore they were assumed to be periodontitis stage 3 or 4 patients. In Windael and co-workers (2021), the definition of severe periodontitis was radiographic bone loss exceeding 1/3 of the root length, whereas in Dierens and co-workers (2012) no patients presented periodontitis at the time of implant placement.

All studies analysed peri-implant disease and implant loss on implant level. Dierens and co-workers (2012) also reported on implant loss on patient level. Implant-based data can be biased due to a small subject population with a large number of implants, and care has to be taken when interpreting the results (Ramanauskaite et al., 2014).

Peri-implant mucositis is today considered the precursor of peri-implantitis (Jepsen et al., 2015), and is also considered reversible (Berglundh et al., 2018). Treatment of peri-implant mucositis before it proceeds to peri-implantitis is therefore crucial. Of the two studies including both severe periodontitis and mild/no periodontitis, only the study by Windael and co-workers (2021) reported on peri-implant mucositis. A total of 56 implants in 18 patients were diagnosed with peri-implant mucositis. However, the study did not specify which of the populations these patients were a part of. Therefore, a comparison on this parameter relative to the periodontal condition could not be done. This results in loss of important information concerning the prevalence of peri-implant mucositis in the two subgroups.

In 2017, the American Academy of Periodontology (AAP) and the European Federation of Periodontology (EFP) presented a new classification system for periodontal and peri-implant

diseases and conditions (Berghlundh et al., 2018; Caton et al., 2018). This implies that no study included in this analysis commenced after the implementation of the new classification system, but hopefully uniform definitions and criteria for diagnosis will result in a clearer data for the future.

The implementation of implant maintenance therapy may potentially prevent peri-implant diseases and lengthen the long-term success and survival rates. This was described by Howe in 2017, where a meta-analysis was done on the effect of prevention and treatment on peri-implant mucositis and peri-implantitis. However, peri-implant diseases may still occur even with good maintenance treatment (Howe, 2017). Further research on peri-implant health and diseases in populations with established maintenance treatments, could give a different outlook on onset, incidence and prevalence of peri-implant diseases and implant loss in the future.

CONCLUSION

The present systematic review including only studies with ≥10-year follow-up suggests and confirms that patients with severe periodontitis are at a higher risk of peri-implantitis, with a three to five times higher incidence rate. The findings also suggest that patients with severe periodontitis are more likely to experience implant loss as compared to those without or with mild periodontitis. For peri-implant mucositis and peri-implant health, there is a paucity of data in the literature in studies with long-term follow-up. More research with long-term follow-up is warranted.

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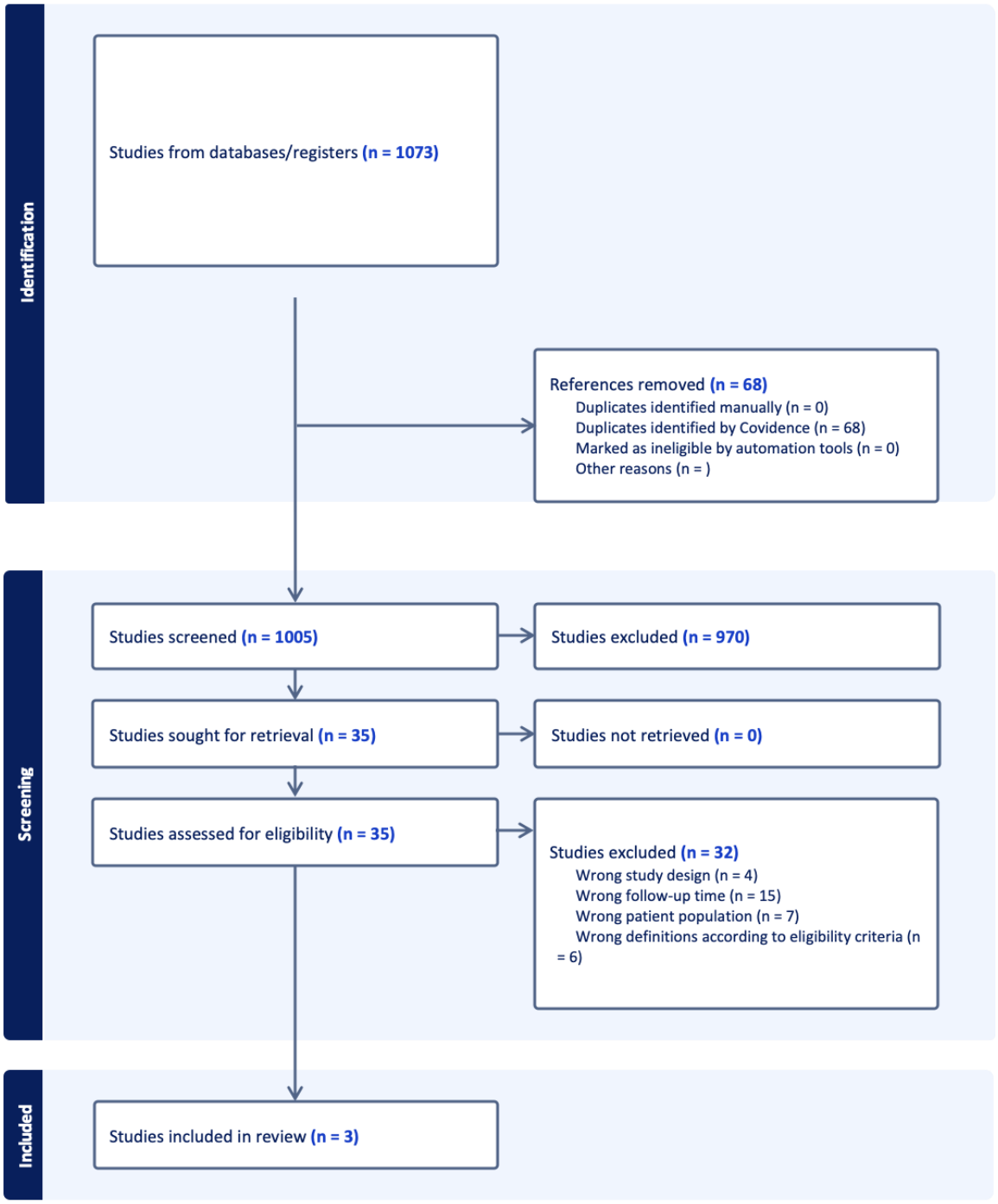
FIGURES

Figure 1. Flow-chart illustrating the screening and selection of studies. Figure created in Covidence (www.covidence.org/) (Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia).



TABLES

Table 1. Table listing excluded studies with title, authors, year published, and the reason for exclusion.

Title	Authors	Published (year)	Reason for exclusion
A 12-year retrospective analytic study of the implant survival rate in 177 consecutive maxillary sinus augmentation procedures	Cho-Lee G.Y.; Naval-Gias L.; Castrejon-Castrejon S.; Capote-Moreno A.L.; Gonzalez-Garcia R.; Sastre-Perez J.; Munoz-Guerra M.F.	2010	Follow-up time not ≥10 years for all participants
A comparison of characteristics of implant failure and survival in periodontally compromised and periodontally healthy patients: A clinical report	Rosenberg E.S.; Cho S.-C.; Elian N.; Jalbout Z.N.; Froum S.; Evian C.I.	2004	Follow-up time not ≥10 years for all participants
A long-term follow-up of 76 Brånemark single-tooth implants	Haas, R.; Polak, C.; Fürhauser, R.; Mailath-Pokorny, G.; Dörtbudak, O.; Watzek, G.	2002	Follow-up time not ≥10 years for all participants
A retrospective analysis of biological complications of implant-supported fixed dental prostheses	Almutairi Z.; Atieh M.; Amirrad F.	2022	Disease definitions not according to eligibility criteria
A retrospective cohort study of peri-implant condition in Chinese patients with different periodontal condition and maintenance frequency	Xie, Y.; Meng, H.; Han, J.; Xu, L.; Zhang, L.; Li, W.	2018	Disease definitions not according to eligibility criteria
A retrospective cohort study on peri-implant complications in implants up to 10 years of functional loading in periodontally compromised patients.	Pandolfi, Andrea; Rinaldo, Francesca; Pasqualotto, Debora; Sorrentino, Fabiola; La Torre, Giuseppe; Guerra, Fabrizio	2019	Follow-up time not ≥10 years for all participants
A systematic review of implant outcomes in treated periodontitis patients.	Sousa, Vanessa; Mardas, Nikos; Farias, Bruna; Petrie, Aviva; Needleman, Ian; Spratt, David; Donos, Nikolaos	2016	Study design not according to eligibility criteria
An 11-Year Retrospective Research Study of the Predictive Factors of Peri-Implantitis and Implant Failure: Analytic-Multicentric Study of 1279 Implants in Peru.	Mayta-Tovalino, Frank; Mendoza-Martiarena, Yens; Romero-Tapia, Percy; Alvarez-Paucar, Maria; Galvez-Calla, Luis; Calderon-Sanchez, Juan; Bolanos-Cardenas, Rodolfo; Diaz-Sarabia, Antonio	2019	Study design not according to eligibility criteria
Assessment of correlation of periodontitis in teeth adjacent to implant and peri-implantitis.	Achanur, Mahantesh; Aldhuwayhi, Sami; Parihar, Anuj Singh;	2020	Follow-up time not ≥10 years for all participants

	Bhardwaj, Atul; Das, Rahul; Anad, K S		
Clinical outcomes of dental implants in patients with and without history of periodontitis: A 20-year prospective study.	Roccuzzo, Andrea; Imber, Jean-Claude; Marruganti, Crystal; Salvi, Giovanni E; Ramieri, Guglielmo; Roccuzzo, Mario	2022	Disease definitions not according to eligibility criteria
Complication and failure rates of fixed dental prostheses in patients treated for periodontal disease.	Bragger, Urs; Hirt-Steiner, Stefanie; Schnell, Natascha; Schmidlin, Kurt; Salvi, Giovanni E; Pjetursson, Bjarni; Matuliene, Giedre; Zwahlen, Marcel; Lang, Niklaus P	2011	Follow-up time not ≥10 years for all participants
Does a history of periodontal disease affect implant survival?	Young, L.; Grant, R.; Brown, T.; Lamont, T.	2021	Study design not according to eligibility criteria
Effect of Soft Tissue Condition on Peri-implant Health and Disease: A Retrospective Clinical Study	Kadkhodazadeh, M.; Amid, R.; Moscowchi, A.	2022	Study design not according to eligibility criteria
History of chronic periodontitis is a high-risk indicator for peri-implant disease.	Casado, Priscila Ladeira; Pereira, Marcelo Constante; Duarte, Maria Eugenia Leite; Granjeiro, Jose Mauro	2013	Follow-up time not ≥10 years for all participants
Implant outcomes poorer in patients with history of periodontal disease.	Veitz-Keenan, Analia; Keenan, James R	2017	Study design not according to eligibility criteria
Long-term implant survival and success: a 10-16-year follow-up of non-submerged dental implants.	Simonis, Pierre; Dufour, Thomas; Tenenbaum, Henri	2010	Wrong definitions according to eligibility criteria
Long-term results of mandibular implants supporting an overdenture: implant survival, failures, and crestal bone level changes	Ueda T.; Kremer U.; Katsoulis J.; Mericske-Stern R.	2011	Study design not according to eligibility criteria
Long-term Survival of Straumann Dental Implants with TPS Surfaces: A Retrospective Study with a Follow-up of 12 to 23 Years.	Becker, Stephan T; Beck-Broichsitter, Benedicta E; Rossmann, Christian M; Behrens, Eleonore; Jochens, Arne; Wiltfang, Jorg	2016	Study design not according to eligibility criteria
Medium- and Long-Term Survival Rates of Implant-Supported Single and Partial Restorations at a Maximum Follow-up of 12 Years: A Retrospective Study.	Corbella, Stefano; Alberti, Alice; Calciolari, Elena; Francetti, Luca	2021	Follow-up time not ≥10 years for all participants
Mucositis, peri-implantitis, implant success, and survival of implants in patients with treated generalized aggressive periodontitis: 3- to 16-year results of a prospective long-term cohort study.	Swierkot, Katrin; Lottholz, Peer; Flores-de-Jacoby, Lavin; Mengel, Reiner	2012	Follow-up time not ≥10 years for all participants
Nine- to fourteen-year follow-up of implant treatment. Part I: implant loss and associations to various factors.	Roos-Jansaker, Ann Marie; Lindahl, Christel; Renvert, Helena; Renvert, Stefan	2006	Follow-up time not ≥10 years for all participants

Osseointegrated implants in subjects treated for generalized aggressive periodontitis: 10-Year results of a prospective, long-term cohort study	Mengel, R.; Behle, M.; Flores-de-Jacoby, L.	2007	Study design not according to eligibility criteria
Peri-implantitis	Algraffee H.; Borumandi F.; Cascarini L.	2012	Study design not according to eligibility criteria
Prevalence and predictive factors for peri-implant disease and implant failure: a cross-sectional analysis.	Daubert, Diane M; Weinstein, Bradley F; Bordin, Sandra; Leroux, Brian G; Flemming, Thomas F	2015	Follow-up time not ≥10 years for all participants
Risk Characteristics of Peri-Implant Infections: A Retrospective Evaluation in a University Consultation Setting.	Schwartzenberg, Achim V; Liu, Chun Ching; Sahrmann, Philipp; Schmidlin, Patrick R; Jung, Ronald E; Naenni, Nadja	2022	Follow-up time not ≥10 years for all participants
Risk factors for dental implant failure and medicolegal implications	Hainarosie R.; Pietrosanu C.; Cherecheanu A.P.; Stoian A.P.; Stefanescu C.D.; Pituru S.M.	2019	Study design not according to eligibility criteria
Supportive periodontal therapy and periodontal biotype as prognostic factors in implants placed in patients with a history of periodontitis	Aguirre-Zorzano L.-A.; Vallejo-Aisa F.-J.; Estefania-Fresco R.	2013	Study design not according to eligibility criteria
Survival and complications: A 9- to 15-year retrospective follow-up of dental implant therapy.	Adler, Lottie; Buhlin, Kare; Jansson, Leif	2020	Follow-up time not ≥10 years for all participants
Ten-year results of a three-arm prospective cohort study on implants in periodontally compromised patients. Part 1: implant loss and radiographic bone loss.	Roccuzzo, Mario; De Angelis, Nicola; Bonino, Luca; Aglietta, Marco	2010	Study design not according to eligibility criteria
Ten-year results of a three arms prospective cohort study on implants in periodontally compromised patients. Part 2: Clinical results	Roccuzzo, M.; Bonino, F.; Aglietta, M.; Dalmasso, P.	2012	Study design not according to eligibility criteria
The correlation between history of periodontitis according to staging and grading and the prevalence/severity of peri-implantitis in patients enrolled in maintenance therapy	Ravidà, A.; Rodriguez, M.V.; Saleh, M.H.A.; Galli, M.; Qazi, M.; Troiano, G.; Wang, H.-L.; Moreno, P.G.	2021	Follow-up time not ≥10 years for all participants
The Stages and Grades of Periodontitis Are Risk Indicators for Peri-Implant Diseases-A Long-Term Retrospective Study.	Yamazaki, Mikiko; Yamazaki, Kosaku; Baba, Yuh; Ito, Hiroshi; Loos, Bruno G; Takahashi, Keiso	2022	Follow-up time not ≥10 years for all participants

Table 2. Characteristics of included studies.

Title	Authors	Published (year)	Definition of periodontitis	Definition of peri-implant health	Definition of peri-implant mucositis	Definition of peri-implantitis
Long-term follow-up of turned single implants placed in periodontally healthy patients after 16-22 years: Radiographic and peri-implant outcome.	Dierens M.; Vandeweghe S.; Kisch J.; Nilner K.; de Bruyn H.	2012	"All patients were in good periodontal health at implant placement."	No definition	No definition	"[bone loss] surpassing the third thread (>2.7 mm)."
Long-term implant prognosis in patients with and without a history of chronic periodontitis: a 10-year prospective cohort study of the ITI Dental Implant System.	Karoussis, Ioannis K; Salvi, Giovanni E; Heitz-Mayfield, Lisa J A; Bragger, Urs; Hammerle, Christoph H F; Lang, Niklaus P	2003	Patients with tooth loss due to chronic periodontitis (≥ stage 3)	No definition	No definition	"Peri-implantitis was defined as an incidence of PPD≥5 mm with BoP and radiographic signs of bone loss."
Early peri-implant bone loss as a predictor for peri-implantitis: A 10-year prospective cohort study.	Windael, Simon; Collaert, Bruno; De Buyser, Stefanie; De Bruyn, Hugo; Vervaeke, Stijn	2021	"History of periodontitis, based on the following preoperative conditions: (a) radiographic evidence of bone loss exceeding 1/3 of the root length of remaining teeth at time of referral, (b) patients treated before implant therapy with (non)surgical periodontal treatment, (c) patients with hopeless teeth, which were extracted due		"Peri-implant mucositis was defined for each individual implant as bleeding and/or suppuration on gentle probing and in absence of bone loss."	"Peri-implantitis was defined as mucositis together with a probing pocket depth equal or above 6 mm and/or bone loss equal or above 3 mm."

			to periodontitis prior to implant placement, (d) edentulous patients at the time of referral with evidence of periodontitis based on radiographs obtained in retrospect from the referring dentist.”			

Table 3. Table presenting data for peri-implant health in patients with no/mild periodontitis (NP) and patients with severe periodontitis (PP) on both implant- and patient level. NR indicates not recorded.

Authors and year	**Patients with no/mild periodontitis (NP)**	**Patients with severe periodontitis (PP)**	**Peri implant health rate in NP**	**Peri-implant health rate in PP**
Dierens et al. (2012)	59 implants in 50 patients	None (One developed periodontitis over the follow-up)	Implant level: 11/59 implants (18,6%) Patient level: NR	NR
Karoussis et al. (2003)	91 implants in 45 patients	21 implants in 8 patients	NR	NR
Windael et al. (2021)	455 implants in 207 patients	897 implants in 200 patients	NR	NR

Table 4. Table presenting data for peri-implant mucositis in patients without or with mild periodontitis (NP) and patients with severe periodontitis (PP) on both implant- and patient level. NR indicates not recorded. When calculating peri-implant mucositis and peri-implantitis rates, three lost implants were not included in the total, because reasons for implant loss were not accounted for.

Authors and year	**Patients with no/mild periodontitis (NP)**	**Patients with severe periodontitis (PP)**	**Peri implant mucositis in NP**	**Peri-implant mucositis in PP**
Dierens et al. (2012)	59 implants in 50 patients	None (One developed periodontitis over the follow-up)	Implant level: 45/59 (76.3%)	NR
Karoussis et al. (2003)	91 implants in 45 patients	21 implants in 8 patients	NR	NR
Windael et al. (2021)	455 implants in 207 patients	897 implants in 200 patients	56 implants (3.8%) in 18 patients (4.4%) were diagnosed with peri-implant mucositis.	

Table 5. Table presenting data for peri-implantitis in patients with no/mild periodontitis (NP) and patients with severe periodontitis (PP) on both implant- and patient level. NR indicates not recorded.

Authors and year	**Patients with no/mild periodontitis (NP)**	**Patients with severe periodontitis (PP)**	**Peri-implantitis rate in NP**	**Peri-implantitis rate in PP**
Dierens et al. (2012)	59 implants in 50 patients	None	Implant level: 3/59 (5.1%) Patient level: NR	NR
Karoussis et al. (2003)	91 implants in 45 patients	21 implants in 8 patients	Implant level: 5/91 (5.5%*) Patient level: NR	Implant level: 6/21 (28.6%) Patient level: NR
Windael et al. (2021)	455 implants in 207 patients	897 implants in 200 patients	Implant level: 24/455 (5.3%) ** Patient level: NR	Implant level: 140/897 (15.6%) ** Patient level: NR

* Karoussis and co-workers (2003) reported the rate of peri-implantitis to be 5.8%, calculated as 5 of 91 implants. In this analysis, the rate of peri-implantitis is calculated to be 5.5%.

** Not all implants included in analysis. Windael and co-workers (2021) reported a total peri-implantitis rate on implant level to be 11.8%, which differs from this analysis' calculation based on Windael and co-workers' data in table 3 and 4 (Windael et al., 2021). In this analysis, the total peri-implantitis rate on implant level is calculated to be 12.1%.

Table 6. Table presenting data for implant loss in patients with no/mild periodontitis (NP) and patients with severe periodontitis (PP) on both implant- and patient level. NR indicates not recorded.

Authors and year	**Patients with no/mild periodontitis (NP)**	**Patients with severe periodontitis (PP)**	**Implant Loss Rate in NP**	**Implant Loss Rate in PP**
Dierens et al. (2012)	62 implants in 50 patients	None	Implant level: 3/62 (4.8%) Patient level: 2/50 (4%)	NR
Karoussis et al. (2003)	91 implants in 45 patients	21 implants in 8 patients	Implant level: 3/91 (3.3%) Patient level: NR	Implant level: 2/21 (9.5%) Patient level: NR
Windael et al. (2021)	455 implants in 207 patients	897 implants in 200 patients	Implant level: 10/455 (2.2%) * Patient level: NR	Implant level: 56/897 (6.2%) * Patient level: NR

* Not all implants included in analysis