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SYSTEMATIC REVIEW

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Efficacy of rehabilitation with different approaches of implant-supported full-arch prosthetic designs: A systematic review

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Abstract

Aim: To evaluate the efficacy of different types of rehabilitation with fixed or removable full-arch implant-supported prosthesis designs in terms of implant loss and success in patients with at least one edentulous jaw, with tooth loss mainly due to periodontitis.

Materials and methods: Clinical studies with at least 12 months reporting on implant loss and implant success were searched. Meta-analysis was conducted to estimate cumulative implant loss considering different prostheses designs.

Results: A total of 11 studies with unclear to low risk of bias were included in the analysis. Estimated cumulative implant loss for fixed prostheses within 1 year and 5 years was 0.64% (95% confidence interval [CI]: 0.31%–1.31%) and 1.85% (95% CI: 0.85%–3.95%), respectively. The corresponding values for removable prostheses amounted to 0.71% (95% CI: 0.22%–2.28%) and 4.45% (95% CI: 2.48%–7.85%). Peri-implantitis affected 10%–50% of the patients restored with implant-supported fixed prostheses.

Conclusions: Based on the limited low-quality data, the present analysis points to a low and similar cumulative implant loss within 1 year for patients with tooth loss mainly due to stage IV periodontitis restored with either removable or fixed implant-supported full-arch prosthesis. At 5 years of functioning, there was a tendency for better outcomes using fixed designs.

KEYWORDS
edentulous, full-arch restoration, peri-implant disease, prevalence, systematic review

Clinical Relevance

Scientific rationale for study: This systematic review summarizes current evidence of the efficacy of various types of rehabilitation employing fixed or removable full-arch implant-supported prosthesis designs in patients with at least one edentulous jaw, with tooth loss mainly due to periodontitis.

Principal findings: Generally low and comparable cumulative implant losses within a 1-year period were detected for patients restored with either removable or fixed implant-supported full-arch prosthesis designs. Within 5 years of follow-up, higher cumulative implant losses were estimated for removable compared to fixed protheses. Existing clinical data did not allow for the assessment of medium-term to long-term (i.e., >5 years) implant loss by considering various prosthesis designs.

Practical implications: In terms of implant loss, fixed prosthesis designs may be beneficial in the rehabilitation of edentulous jaws, with tooth loss mainly due to stage IV periodontitis.

1 | INTRODUCTION

Dental-implant-supported reconstructions have become a frequent treatment option for the rehabilitation of partially and fully edentulous jaws (Goodacre & Naylor, 2016). Full-arch implant-supported fixed dental prostheses may provide advantages over conventional treatment options, such as comfort, substantial improvements in prosthetic function, adaptation, and stability (Fueki et al., 2007; Emami & Thomason, 2013; Harris et al., 2013).

Despite the well-documented high survival rates noted for dental implants (Chappuis et al., 2013), complications may still arise. In fact, there is strong evidence from longitudinal and cross-sectional studies pointing to an increased risk of developing peri-implantitis in patients who have lost their teeth due to periodontitis (odds ratio [OR] = 4.5–19; Renvert et al., 2014; de Araujo Nobre et al., 2015). Recent data also point to an association between prosthetic features and peri-implantitis, which, in turn, might be of crucial relevance for patients who have a history of chronic periodontitis (Y. Yi et al., 2020). Specifically, over-contoured implant-supported restorations, splinted implants, and a prosthetic margin to crestal bone distance of ≤1.5 mm were shown to be the factors related to the diagnosis of peri-implantitis (Derks et al., 2016; Y. Yi et al., 2020). Furthermore, one recent systematic review noted a tendency towards a higher frequency of peri-implantitis among edentulous patients restored with implant-supported overdentures compared to those restored with full-arch fixed restorations (Ramanauskaite et al., 2021). Nevertheless, because of the limited number of comparative studies, no conclusive evidence could be reached regarding the impact of prosthesis designs on peri-implant tissue health and stability (Ramanauskaite et al., 2021).

Therefore, the present systematic review aimed at addressing the following PICOS question: "In patients with at least one edentulous jaw, with tooth loss mainly due to periodontitis (Population), what is the efficacy of different types of rehabilitation with fixed or removable full-arch implant-supported prosthesis designs (Intervention and Comparison), in terms of implant loss and success rates (Outcome), as reported in prospective and retrospective observational one-arm and case-series, randomized, and non-randomized controlled clinical trials (Study design)?"

2 | MATERIAL AND METHODS

The review protocol was developed and structured according to the PRISMA (Preferred Re-porting Items for Systematic Review and Meta-Analyses) statement (Moher et al., 2009). The review was registered in PROSPERO, an international prospective register of systematic reviews (registration number: CRD42020176578).

2.1 | Focus question

In patients with at least one edentulous jaw, with tooth loss mainly due to periodontitis (*Population*), what is the efficacy of different types of rehabilitation with fixed or removable full-arch implant-supported prosthesis designs (*Intervention and Comparison*), in terms of implant loss and success rates (*Outcome*), as reported in prospective and retrospective observational one-arm and case-series, randomized and non-randomized controlled clinical trials (*Study design*)?

Population: Patients with at least one edentulous jaw, with tooth loss mainly due to periodontitis (stage IV or equivalent). All definitions of periodontitis were accepted.
Intervention: Different types of rehabilitation with complete implant-supported fixed or removable restorations in mandibular or maxillary dental arches.
Comparison: Different types of rehabilitation.
Outcome: *Primary outcomes*: Implant loss and success rates (i.e., changes in clinical parameters, including bleeding index [BI]/bleeding on probing [BOP], plaque index [PI], probing depth [PD], occurrence of peri-implant mucositis and peri-implantitis). *Secondary outcomes*: Radiographic marginal bone level (MBL) changes, patient-reported outcome measures (PROMs; assessed with questionnaires or other tools used in respective studies), survival of restorations, technical complications, and economic aspects.
Study design: To broaden the number of available studies for inclusion, prospective and retrospective observational one-arm and case-series, randomized, and non-randomized controlled clinical trials were searched.

2.2 | Inclusion and exclusion criteria

Inclusion criteria were as follows:

1. Randomized controlled clinical trials (RCTs), controlled clinical trials (CCTs), prospective and retrospective observational one-arm clinical studies and case-series with at least 12 months of follow-up including patients with at least one edentulous jaw and tooth loss mainly due to periodontitis rehabilitated with fixed or removable implant-supported prostheses, reporting on implant survival/loss and implant success by the means of changes in clinical parameters (BI/BOP, PI, PD) and/or occurrence of peri-implant mucositis and peri-implantitis.
2. Studies reporting on prosthesis design, number of implants, timing of implant placement (type I–IV implant placement (Hämmerle et al., 2004) and time to loading (i.e., conventional/immediate).

Exclusion criteria were the following:

1. Animal studies;
2. Case reports and cross-sectional studies;
3. Studies using narrow diameter implants (≤3 mm diameter) and/or short implants (<6 mm);
4. Studies with a follow-up period of less than 1 year;
5. Studies reporting on zygomatic implants;
6. Articles published in languages other than English.

2.3 | Information source and search

Two electronic databases (PubMed and Cochrane database) were searched for relevant articles published until March 2020. The following search filters were applied: "humans" and "clinical trial". The search was restricted to English language.

The following MeSH and free-text search terms were used:

Population
edentulous jaws [MeSH] OR edentulous maxilla OR edentulous mandible OR edentulous ridge OR complete edentulism
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 OR fixed complete prostheses
Outcome
dental implant survival [Mesh term] OR cumulative survival rate [Mesh term] OR bleeding on probing [Mesh term] OR plaque index OR probing depth OR marginal bone loss OR periimplantitis [Mesh term] OR peri-implantitis OR peri-implant infection OR periimplant infection OR peri-implantitis OR biological complications OR mucositis [Mesh term] OR patient reported outcomes [Mesh term]
Population AND Intervention AND Outcome

2.4 | Study selection

During the first literature selection stage, according to the defined inclusion criteria, the titles and abstracts of all identified studies were screened for eligibility by two independent reviewers (AR and FL). In the second stage, the full texts of potentially eligible articles were reviewed and evaluated according to the aforementioned exclusion criteria. In case of missing or incomplete information, the publications were excluded. Differences between reviewers were resolved by discussion and consultation with the third reviewer (FS). The level of inter-examiner agreement for the first and second literature selection stages was expressed by Cohen's-kappa scores.

2.5 | Data collection

Two reviewers independently performed data collection in duplicate for the primary and secondary outcomes. The following data were retrieved by two independent reviewers and extracted into predefined templates:

- General and patient-related information: study design, follow-up period, setting, study funding, number of patients and implants, jaw (maxilla/mandible), and patient-related information, including age, gender, smoking status, periodontal status, and supportive maintenance programme (Tables 1 and 2);
- Implant and prosthetic design-related data: implant type/brand, upper/lower jaw, number of implants placed per jaw/ distribution, bone augmentation procedures, time of implant placement (immediate/delayed), two- or one-stage implant placement, prosthetic design (hybrid/overdenture), type of attachment, opposing dentition (partially edentulous/fully edentulous), and loading protocol (conventional/immediate);
- Treatment outcomes: implant loss/survival (%); changes in clinical parameters (PI, modified plaque index (mPI), BI, BOP, probing pocket depth (PPD), radiographic MBL); case definitions for peri-implant diseases; prevalence of peri-implant mucositis and/or peri-implantitis, and additional observations related to the prevalence of peri-implant diseases; PROMs; economical aspects; survival of restorations, and technical complications (Tables 3 and 4, Supplement 5).

2.6 | Risk of bias in individual studies

The Cochrane Collaboration's tool for assessing risk of bias (RoB 2) was used in the case of controlled clinical trials, whereas the RoB 1 tool was employed for the non-randomized studies (Sterne et al., 2016; Supplement 1).

2.7 | Data analyses

Analyses were carried out to calculate estimated implant survival/loss rates considering prosthesis designs (i.e., fixed and removable) (Kern et al., 2016). Retrospective and prospective study designs were included in the meta-analysis. Sensitivity analysis was performed to identify potential outliers of influential studies. For each included study, the 1- and 5-year cumulative event rates (implant losses) were estimated as reported previously (Kirkwood & Sterne, 2003a, 2003b; Pjetursson et al., 2004). In brief, the number of implant losses was assumed to be Poisson-distributed, and event rates were calculated based on the survival function $S(T) = \exp(-T\times \text{ event rate})$, with T being the observation period considering implant as a statistical unit (Kirkwood & Sterne, 2003a, 2003b). Meta-analysis on One-Proportion was then conducted using a random-effects model estimated based on the DerSimonian and Laird (DL) method (DerSimonian & Laird, 1986). The summary effect was estimated as the weighted average of the effect sizes of individual studies. Logit transformation was used to ensure normal distribution of proportions. Heterogeneity was

TABLE 1 General information: Fixed prostheses

Author	Year	Study type	Follow-up period	Setting	Funding	No. of patients	Patient drop-out	Jaw	No. of implants	Patient age (mean ± SD) (range)	Gender (female/male)	Systemic conditions	Smoking status	Periodontal status	Supportive therapy
1. Adell et al.	1986	Prospective case series	3 years	University	NR	16	1 (6.25%)	Upper: 7 patients Lower: 9 patients	95	53 (32–69)	10/6	NR	NR	All patients totally edentulous as a result of tooth loss from destructive periodontal disease	NR
2. S. W. Yi et al.	2001	Prospective clinical study	3 years	University	NR	6	0	Upper: 1 patient Lower: 5 patients	35	55 (47–61)	1/5	NR	NR	All patients were referred because of advanced periodontal disease	An individual maintenance care was designed for each patients
3. Martens et al.	2014	Prospective case series	5 years	University	NR	33	4 (12%)	Upper: 35 patients Lower: 8 patients	163 Upper: 130 Lower: 33	66 ± 12.8 (39–89)	16/17	Systemically compromised patients excluded	Excluded	All patients were classified as periodontally compromised based on tooth loss at a young age and/or ongoing periodontal disease in remaining teeth	Patients were enrolled in a recall programme to ensure good oral hygiene
4. Tallarico et al.	2016	RCT	5 years	Private practice	NR	40	0	Upper	200	63 (60–84)	19/21	Systemically healthy	Heavy smokers excluded (>10 cig./day); light smokers: 2 (5%) patients	Patients presented with failing dentition defined as presence of bone loss >75% of supporting bone, PD ≥8 mm, class III furcation, hypermobility, and non-treatable endodontic issues	NR
5. Li et al.	2017	Prospective clinical study	5 years (range: 2–7)	University hospital	NR	17	0	7 upper arches, 12 lower arches	76	39.4 (28–45)	7/10	Systemically healthy	Heavy smokers (>15 cig./day) excluded	All patients lost their teeth due to aggressive periodontitis. Definition proposed by CDC/AAP (2007)	Patients received periodontal treatment as necessary during the maintenance periods
6. Cercadillo-Ibarguren et al.	2017	Retrospective case series	1–9 years; median: 50 months	Private practice	NR	56	NA	Upper: 40 patients Lower: 32 patients	378	64 ± 11.1 (41–87)	30/26	NR	Smokers (≥10 cig./day): 162 (6.8%) patients	All patients had a history of periodontal disease	Patients were enrolled in a peri-implant maintenance programme
7. Windael et al.	2018	Prospective clinical study	10 years	University hospital	Dentsply Sirona Grant	25	4 (16%)	Lower	125	68.4 (49–84)	13/8	Systemically healthy	NR	11 patients (44%) lost their teeth due to a history of periodontitis. "*Patients were*	NR

(Continues)

TABLE 1 (Continued)

Author	Year	Study type	Follow-up period	Setting	Funding	No. of patients	Patient drop-out	Jaw	No. of implants	Patient age (mean ± SD) (range)	Gender (female/ male)	Systemic conditions	Smoking status	Periodontal status	Supportive therapy
														classified as patients with or without a history of periodontitis, based on the following criteria: (a) radiographic evidence of bone loss extending one-third of the root length of remaining teeth at time of referral; (b) patients actively treated before implant therapy with (non)surgical periodontal treatment; (c) patients in whom hopeless teeth were extracted due to periodontitis prior to implant treatment; (d) edentulous patients at the time of referral with evidence of periodontitis based on radiographs obtained in retrospect from the referring dentist"	
8. Barootchi et al.	2020	Retrospective cohort study	8.7 ± 3.3 years	University	NR	56	NA	Upper: 40 patients; lower: 16 patients	452: Group 1 (zirconia prostheses) 200 Group 2 (metal–acrylic prostheses) 252	52.9 ± 12.9	43/13	7 (12.5%) diabetes patients	12 (21.4%) smokers	22 (39%) of the patients had a history of periodontitis (i.e., presence of at least 4 sites with clinical attachment loss >3 mm and/or patients who received periodontal treatment)	NR

Abbreviations: NR, not reported; RCT, randomized controlled clinical study.

TABLE 2 General information: Removable prostheses

Author	Year	Study type	Follow-up period	Setting	Funding	No. of patients	Patient drop-out	Jaw	No. of implants	Patient age (mean ± SD (range)	Gender (female/ male)	Systemic conditions	Smoking status	Periodontal status	Supportive therapy
1. Van Assche et al.	2012	Prospective study	2 years	University	NR	12	0	Upper	72	58.6 (47.7–71.3)	5/7	Systemically healthy	6 (50%) smokers	The main reason for tooth extraction was periodontitis (10/12 patients) and two patients were already edentulous in maxilla	NR
2. Eccellente et al.	2011	Prospective study	26.7 months (range: 12–54 months)	Private practice	NR	45	0	Upper	180	60; range: 43–76	18/27	Systemically healthy	33 (73%)	Periodontitis was mentioned as one of the reason for tooth loss	NR
3. Zou et al.	2013	Retrospective study	6.5 years (5–8 years)	University	NR	44 Group 1 (telescopic crowns retention): 21 Group 2 (bar retention): 23	3 (6.8%)	Upper	217	Group 1: 55.9 ± 6.3 Group 2: 59.6 ± 5.6	Group 1: 9/12 Group 2: 11/12	Systemically healthy	Smokers excluded	Reason for edentulism was periodontitis or periapical disease	NR

Abbreviation: NR, not reported.

TABLE 3 Outcomes: Fixed prostheses

Author	Year	Implant loss/ survival (%)	Radiographic bone level changes	PI	mPI	BI	mBI	SBI	BOP	PD	Definition of peri-implant disease	Prevalence of PI disease
1. Adell et al.	1986	Loss: 0% Survival: 100%	Baseline: 0 3 years: 1.01 ± 0.4	NR	NR	NR	NR	NR	15%–20% of implants	Baseline: 3.8 ± 0.8 3-years: 2.9 ± 0.8	NR	NR
2. S.W.Yi et al.	2001	Loss: 0% Survival: 100%	0.22 (−1.0 to 1.0)	NR	NR	NR	NR	NR	NR	NR	PM: visual signs of inflammation of the peri-implant mucosa, such as redness, swelling, or suppuration	0
3. Martens et al.	2014	During the first year: 6 implants in 4 patients Within 1 and 5 years: 3 implants in 1 patient Survival: 96.3%	Mean total crestal bone loss: 1.6 ± 0.77; range: 0–3.35 mm	NR	NR	NR	NR	NR	Present around 80% of implants	3.4 ± 0.70; range: 1.5–6.0 mm 5.4% of implants had PD > 5 mm	PI: MBL > 2.1 mm + PD > 5 mm	1.5% implants
4. Tallarico et al.	2016	Test: 6 implants lost Survival: 95% Control: 1 implant lost Survival: 98.75% Total survival: 93.75%	Test: 1.71 ± 0.42 Control: 1.51 ± 0.3 Mean marginal bone level changes from baseline to 5 years not statistically different between groups: 0.20 ± 0.06, 95% CI 0.08%–0.18%, $p = .117$	Test: 20% Control: 9.2%	NR	NR	NR	Test: positive SBI 7.5% implants; Control: 6.25% implants	NR	NR	PI: unclear definition	Group 1: 3 (15%) patients Group 2: 2 (10%) patients
5. Li et al.	2017	1 implant lost due to peri-implantitis 4 months following the placement Survival: 98.75%	Strait implants 1 year: 0.8 ± 0.4 (80 implants); 3 years: 0.9 ± 0.4 (76 implants); 5 years: 1.0 ± 0.3 (44 implants); 7 years: 1.27 ± 0.3(32 implants) Tilted implants 1 year: 0.9 ± 0.4 (80 implants); 3 years: 0.9 ± 0.4 (76 implants); 5 years:	1.2 ± 0.4	NR	0.5 ± 0.5	NR	NR	NR	3.0 ± 0.5	PI: PD > 4 mm + ongoing bone loss	1 (1.25%) implant

(Continues)

TABLE 3 (Continued)

Author	Year	Implant loss/ survival (%)	Radiographic bone level changes	PI	mPI	BI	mBI	SBI	BOP	PD	Definition of peri-implant disease	Prevalence of PI disease
			1.1 ± 0.4 (44 implants); 7 years: 1.2 ± 0.4 (32 implants)									
6. Cerca-dillo-Ibarguren et al.	2017	2 implants lost in 2 patients Survival: 99.5% (implant-level) 96.4% (patient-level)	NR	1.5 ± 0.9	NR	NR	NR	NR	NR	2.4 ± 1.2 mm; range: 1–12 mm	PM: BOP + changes in bone level ≤ 1.5 mm, no suppuration PI: bone loss >1.5 mm + BOP and/or suppuration	PM: 56.9% implants and 50% patients PI: 14.3% implant and 50% patients
7. Windael et al.	2018	Loss: 0% Survival: 100%	2-Years: 0.17 ± 0.27, 10-years: 0.49 ± 1.08	0.51 ± 0.41	NR	NR	NR	NR	2-year: 0.55 ± 0.41; 10-year: 0.28 ± 0.36	2-year: 2.45 ± 0.59; 10-year: 3.73 ± 0.73	PI: MBL >2 mm + BOP	4.8% implants
8. Barootchi et al.	2020	Loss: 5 1implant Survival: Group 1: 93.7% Group 2: 83% no difference detected between group 1 and group 2	NR	NR	NR	NR	NR	NR	NR	NR	PI: clinical inflammation combined with radiographic marginal bone loss of more than 2 mm after bone remodelling (8th European Workshop on Periodontology)	95 (21%) of implants; no difference detected between group 1 and 2

Abbreviations: BI, bleeding index; BOP, bleeding on probing; mPI, modified plaque index; NR, not reported; PD, probing depth; PI, peri-implantitis; PI, plaque index; PM, peri-implant mucositis; SBI, sulcus bleeding index; SD, standard deviation.

TABLE 4 Outcomes: Removable prostheses

Author	Year	Implant loss/ survival rate (%)	Radiographic bone level changes	PI	mPI	BI	mBI	SBI	BOP	PPD	Definition of peri-implant disease	Prevalence of PI disease	Additional comments
1. Van Assche et al.	2012	1 short implant lost after 2 weeks; 2 short implants in 1 patient lost due to failure in osseointegration Survival: 98.6%	First year: Short implants (6 mm) 0.7; range: 0 to +2.1 mm Long implants (>6 mm): 1.3 mm; range: 0 to +5.1 mm Additional bone loss during second year: Short implants: 0.3 mm; range: 0–2.2 mm Long implants: 0.2 mm; range: 0–1.8 mm.	NR	NR	NR	NR	NR	6 months: short implants: 26% Long implants: 27% 12 months: short implants: 32% Long implants: 44% 2 years: short implants: 27% Long implants: 28%	6 months Short implants: 2.6; range: 2–5 Long implants: 3.2; range: 2–7 12 months Short implants: 3.1; range: 1–6 Long implants: 3.6; range: 2–8 2 years Short implants: 3.2; range: 1–6 Long implants: 3.5; range: 2–8	NR	NR	No significant difference could be found between short (6 mm) and long (>6 mm) implants
2. Eccellente et al.	2011	2 implants lost due to a failure in osseointegration; 1 implants removed due to peri-implantitis; 1 implant lost due to fracture Survival: 97.80%	NR	NR	NR	NR	NR	Modified SBI of 3%–3.97% implants	NR	NR	NR	One implant was removed due to peri-implantitis (0.5%)	NR
3. Zou et al.	2013	Loss: 0% Survival: 100%	Group 1*: First year:0.3 ± 0.3 mm 8 years: 1.2 ± 0.4 Group 2**: First year: 0.8 ± 0.2 mm 8 years: 1.2 ± ±0.6	NR	Group 1: First year: score 0: 75% implants, score 1: 20%, score 2: 5% 8 years: score 0: 50% implants, score 1: 50% Group 2: First year: score 0: 76% implants, score 1: 19%, score 2: 5%. 8 years: score 0: 67% implants, score 1: 33%, score 2: 7%	Group 1: First year: score 0: 85% implants, score 1: 10%, score 2: 5% 8 years: score 0: 50% implants, score 1: 50% Group 2: First year: score 0: 81% implants, score 1: 14%, score 2: 5% 8 years: score 0: 100% implants	NR	NR	NR	Group 1: First year: 2.3 ± 0.5 mm 8 years: 3.0 ± 0.5 Group 2: First year: 2.5 ± 0.6 mm 8 years: 2.8 ± ±0.4	NR	NR	Higher plaque levels were in group 2 (bar-retained)

* - telescopic crowns retention; ** - bar retention.

Abbreviations: BI, bleeding index; BOP, bleeding on probing; mPI, modified plaque index; NR, not reported; PI, peri-implantitis; PI, plaque index; PM, peri-implant mucositis; PPD, probing depth; SBI, sulcus bleeding index; SD, standard deviation.

assessed using I^2 index (Higgins et al., 2003). Results were considered significant if $p < .05$. The metafor R package was used to conduct meta-analysis (R core team 2018 (R Foundation for Statisticsl Computing, Vienna, Austria); Viechtbauer, 2010). Publication bias in meta-analyses of One Proportion has been critically appraised as only observational and therefore non-comparative studies are included; thus they do not report significance which may be related to “undesirable” outcomes or publication bias (Maulik et al., 2011). Since funnel plots for meta-analysis of proportion summarizing a rather low incidence were shown to be frequently asymmetric in the absence of publication bias, funnel plots of study size on the *y*-axis were proposed (Hunter et al., 2014). Funnel plots for study size and standard error are presented in Supplement 2. No meta-analysis was feasible for the clinical and radiographic outcomes.

3 | RESULTS

3.1 | Study selection

Electronic literature search yielded a total of 581 articles (PubMed: 574, Cochrane: 7). After removing irrelevant studies based on the evaluation of titles and abstracts ($n = 450$, kappa $= 0.94$), the remaining 131 articles were selected for full-text analysis. Of these, 120 publications were excluded for various reasons, of which the most frequent was lack of or insufficient reporting on the periodontal status and/or reasons for tooth loss ($n = 73$ publications; Supplement 3). Finally, 11 studies met the inclusion criteria and were eligible for further analysis (see Tables 1 and 2 and Figure 1).

Of the 11 included publications, 8 reported on the efficacy of fixed full-arch implant-supported prostheses (Adell et al., 1986; Martens et al., 2014; Tallarico et al., 2016; Cercadillo-Ibarguren et al., 2017; Li et al., 2017; Windael et al., 2018; Barootchi et al., 2020; S.W.Yi et al. 2001) (Table 1) and the remaining 3 studies reported on the outcomes of removable implant-supported full-arch prostheses (Eccellente et al., 2011; Van Assche et al., 2012; Zou et al., 2013) (Table 2).

No RCTs or prospective controlled clinical studies comparing dental implant outcomes supporting fixed versus removable restorations were identified.

3.2 | Study characteristics

Publications reporting on the clinical performance of fixed full-arch implant-supported prostheses were published between 1996 and 2020, with a mean follow-up period of 1–10 years. The included studies comprised one RCT (Tallarico et al., 2016), five prospective studies (Adell et al., 1986; S. W. Yi et al., 2001; Martens et al., 2014; Li et al., 2017; Windael et al., 2018), and two retrospective clinical studies (Cercadillo-Ibarguren et al., 2017; Barootchi et al., 2020) (Table 1).

Three studies that included patients with removable implant-supported full-arch prostheses were published between 1996 and 2014, and the mean follow-up period ranged from 2 to 6.5 years. Of the three studies, two were prospective studies (Eccellente et al., 2011; Van Assche et al., 2012) and one was a retrospective analysis (Zou et al., 2013) (Table 2).

3.3 | Descriptive results

Summarized results of patient, implant, implant site, and prosthetic characteristics are presented in Tables 1 and 2 and Supplement 4.

3.3.1 | Fixed full-arch implant-supported prostheses

A total of 249 patients (with 137 and 112 included in prospective and retrospective studies, respectively) were restored with fixed full-arch implant-supported prostheses. In the included studies, the mean age of the patients ranged from 39.4 to 68.4 years (17%–77% female). In three studies, 5%–21.4% of the patients were smokers, whereas the remaining five studies did not report patients' smoking status. This group of patients exhibited 1524 implants (with 694 and 830 included in prospective and retrospective studies, respectively). Of these, 64% (977 implants) had a modified surface, 6% ($n = 95$ implants) were non-modified, and for the remaining implants (30%; 452 implants) the surface characteristics were not reported.

Regarding the patients' periodontal status, in two studies, periodontitis was indicated as a reason for tooth loss (Adell et al., 1986; Li et al., 2017), and in one study, 44% of the included population lost their teeth due to periodontitis (Windael et al., 2018). In the remaining studies, either all (S. W. Yi et al., 2001; Martens et al., 2014; Tallarico et al., 2016; Cercadillo-Ibarguren et al., 2017) or part of the patient sample (39%; Barootchi et al., 2020) were diagnosed with periodontitis. Definition of periodontitis was indicated in three of the studies (Table 1; Tallarico et al., 2016; Li et al., 2017; Barootchi et al., 2020). In addition, as indicated in three studies, following the implant placement, all patients were enrolled in a maintenance programme (S. W. Yi et al., 2001; Martens et al., 2014; Cercadillo-Ibarguren et al., 2017; Windael et al., 2018).

3.3.2 | Removable full-arch implant-supported prostheses

A total of 101 patients (with 57 and 44 included in prospective and retrospective studies, respectively) with 469 modified surface implants (with 252 and 217 included in prospective and retrospective studies, respectively) were restored with full-arch implant-supported removable prostheses. The mean age of the patients ranged from 55.9 to 60.0 years (40%–45% female) among the included studies. The proportion of smokers in two studies ranged from 50% to 73%, whereas the remaining study did not report on smoking habits. Periodontitis was indicated as one of the reasons for tooth loss, with no clear definition provided (Table 2; Eccellente et al., 2011; Van Assche et al., 2012; Zou et al., 2013). None of the studies provided information on the patients' enrolment in supportive maintenance.

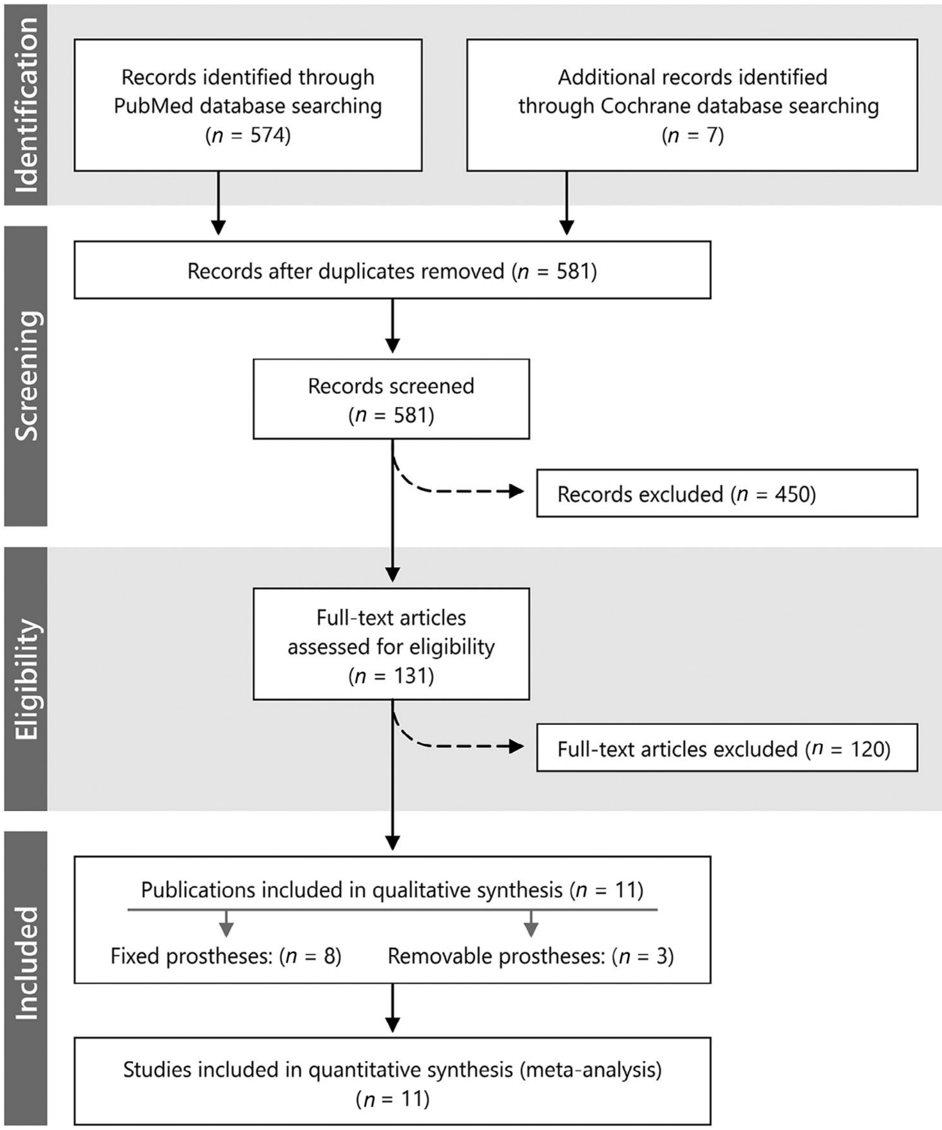

FIGURE 1 Literature search flow-chart

3.4 | Primary outcomes

3.4.1 | Implant loss

Fixed full-arch implant-supported prostheses

Eight studies (six prospective and two retrospective) with a mean follow-up of 5.5 years (range: 3–10 years) were included in meta-analysis (Adell et al., 1986; S. W. Yi et al., 2001; Martens et al., 2014; Tallarico et al., 2016; Cercadillo-Ibarguren et al., 2017; Li et al., 2017; Windael et al., 2018; Barootchi et al., 2020). The estimated cumulative implant loss within the first year was 0.64% (95% CI: 0.31%–1.31%), with low heterogeneity among the eight studies ($I^2 = 0\%$; $p = .80$; Figure 2). The cumulative implant loss within the 5-year period was 1.85% (95% CI: 0.85%–3.95%). Substantial heterogeneity was detected among the studies ($I^2 = 62\%$; $p < .01$; Figure 3). Sensitivity analysis did not reveal any potential outliers for the respective 1- and 5-year follow-up intervals.

Removable full-arch implant-supported prostheses

Meta-analysis was based on three studies (two prospective and one retrospective) with a mean follow-up period of 3.5 years (range: 2–6.5 years) (Eccellente et al., 2011; Van Assche et al., 2012; Zou et al., 2013). The cumulative implant loss within the first year was 0.71% (95% CI: 0.22%–2.28%), with irrelevant heterogeneity among the studies ($I^2 = 0\%$; $p = .65$; Figure 4). Sensitivity analysis did not reveal any potential outliers for 1-year follow-up. For the 5-year follow-up meta-analysis, one potential outlier with retrospective study design was identified (Zou et al., 2013), and the leave-one-out analysis revealed increased estimated weights cumulative mean implant loss of 4.45% (95% CI: 2.48%–7.85%) and also decreased heterogeneity ($I^2 = 0\%$; $p = .54$; Figure 5).

3.5 | Clinical outcomes

Owing to the inconsistencies in reporting among the studies, only descriptive analysis was feasible for the assessed clinical outcomes.

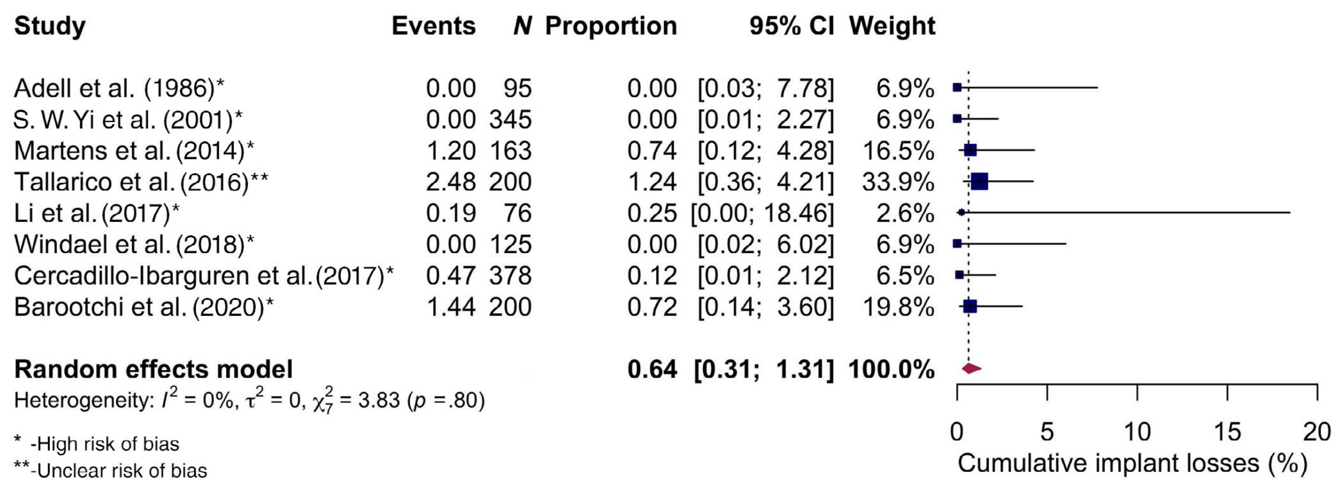

FIGURE 2 Forest plot showing the estimated cumulative implant loss (%) within 1-year period for the fixed prostheses. The column "Events" represents the estimated number of losses within the first year, "N" represents the number of implants, "Proportion" is the respective proportion and 95% confidence interval (95% CI), and "Weight" represents the weight of each individual study in the random-effects model [Colour figure can be viewed at wileyonlinelibrary.com]

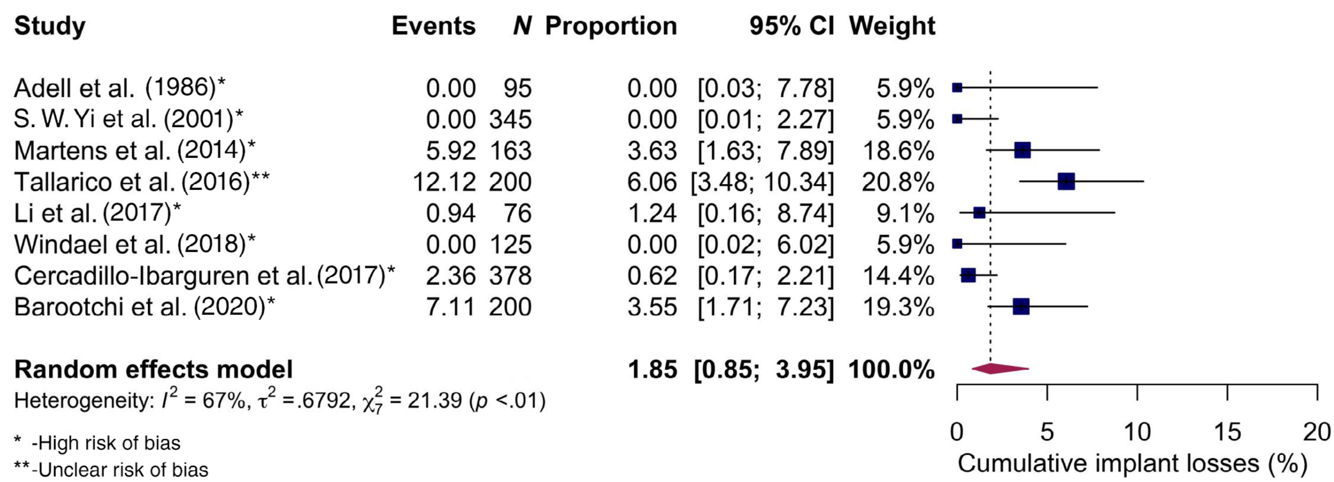

FIGURE 3 Forest plot showing the estimated cumulative implant loss (%) within 5-year period for the fixed prostheses. The column "Events" represents the estimated number of losses within the first year, "N" represents the number of implants, "Proportion" is the respective proportion and 95% confidence interval (95% CI), and "Weight" represents the weight of each individual study in the random-effects model [Colour figure can be viewed at wileyonlinelibrary.com]

3.5.1 | Fixed full-arch implant-supported prostheses

Prospective studies

The mean PI values ranged from 0.51 to 1.2 (mean follow-up period: 5–10 years; Li et al., 2017; Windael et al., 2018). The mean BOP values ranged between 28% (10 years; Windael et al., 2018) and 80% (5 years; Martens et al., 2014). In fact, as noted in one analysis, the mean BOP values decreased from 55% at 2-year follow-up to 28% after 10 years (Windael et al., 2018). The reported mean PD values varied from 2.45 to 3.73 mm (Adell et al., 1986; Martens et al., 2014; Li et al., 2017; Windael et al., 2018). In addition, the mean PD values tended to increase between 2- and 10-year follow-up assessments (2.45 and 3.73 mm, respectively; Windael et al., 2018).

Retrospective studies

One study reported on mean PI and PD values of 1.5 and 2.4 mm, respectively (mean follow-up period: 1–9 years; Cercadillo-Ibarguren et al., 2017).

3.5.2 | Removable full-arch implant-supported prostheses

Prospective studies

Similar mean BOP values were registered at 6-month and 2-year follow-ups (26%–27% and 27%–28%, respectively; Van Assche et al., 2012). The mean reported PD values ranged from 3.2 to 3.5 mm after 2 years (Van Assche et al., 2012).

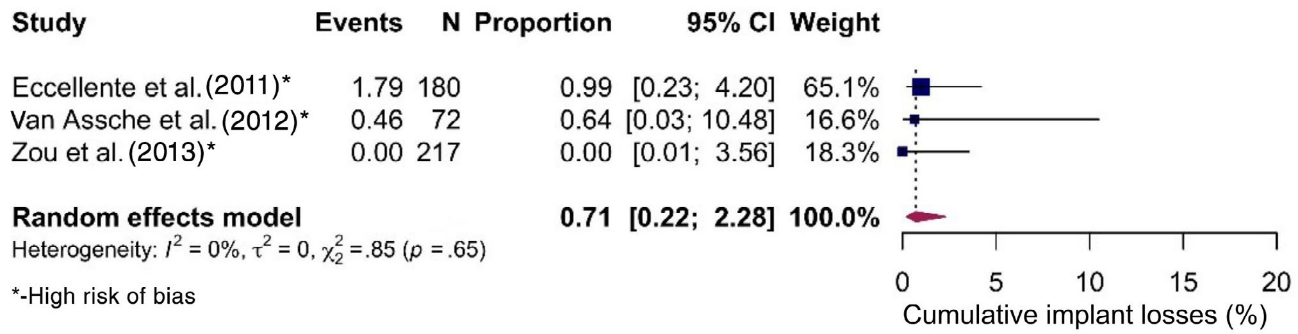

FIGURE 4 Forest plot showing the estimated cumulative implant loss (%) within 1-year period for the removable prostheses. The column "Events" represents the estimated number of losses within the first year, "N" represents the number of implants, "Proportion" the respective proportion and 95% confidence interval (95% CI), and "Weight" represents the weight of each individual study in the random effects model [Colour figure can be viewed at wileyonlinelibrary.com]

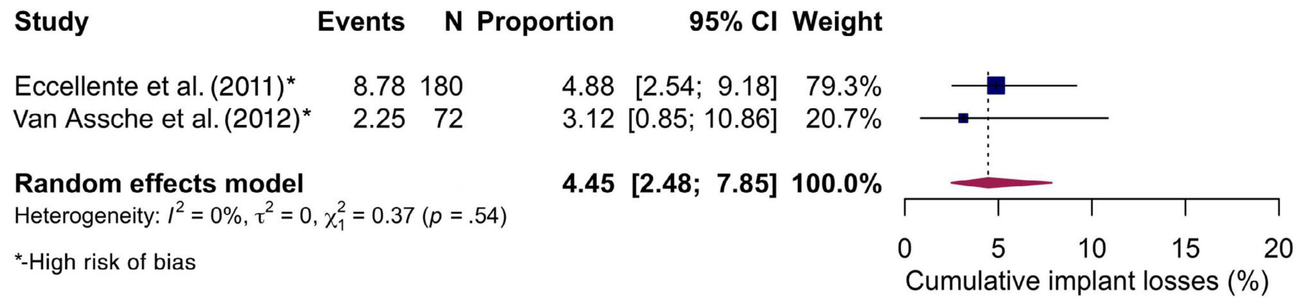

FIGURE 5 Forest plot showing the estimated cumulative implant loss (%) within 5-year period for the removable prostheses. The column "Events" represents the estimated number of losses within the first year, "N" represents the number of implants, "Proportion" the respective proportion and 95% confidence interval (95% CI), and "Weight" represents the weight of each individual study in the random effects model [Colour figure can be viewed at wileyonlinelibrary.com]

Retrospective studies

According to one retrospective analysis, after 1 year of functioning, 75% to 76% of the implants presented absence of plaque, and 81%–85% of implants showed no BOP, whereas after 8 years, the corresponding values were 50%–67% (mPI), and 50%–100% of implants (BI) (Zou et al., 2013). The reported mean PD values ranged from 2.3 to 2.5 mm after a mean follow-up period of 6.5 years (Zou et al., 2013).

3.6 | Prevalence of peri-implant diseases

3.6.1 | Fixed full-arch implant-supported prostheses

Prospective studies

Over a period of 3 years, none of the implants showed signs of peri-implant mucositis (S. W. Yi et al., 2001). Within the 3–10-year follow-up period, 1.25%–4.8% of implants (Martens et al., 2014; Li et al., 2017; Windael et al., 2018) and 10%–15% of patients (Tallarico et al., 2016) were diagnosed with peri-implantitis (Table 3).

Retrospective studies

The reported prevalence of peri-implant mucositis at the implant and patient levels was 56.9% and 50%, respectively (Cercadillo-Ibarguren et al., 2017). The prevalence of peri-implantitis ranged from 14.3% to 21% at the implant level and reached 50% at the patient level (Cercadillo-Ibarguren et al., 2017; Barootchi et al., 2020).

Removable full-arch implant-supported prostheses

Prospective studies. Implant-level peri-implantitis prevalence of 0.5% was reported over the mean follow-up period of 26.7 months for the removable prosthesis design (Eccellente et al., 2011).

Retrospective studies. The included retrospective analysis did not report on peri-implant diseases.

3.7 | Secondary outcomes

3.7.1 | Radiographic outcomes

Fixed full-arch implant-supported prostheses

Prospective studies. Over the 3–10-year period, the mean MBL ranged from 0.22 to 1.71 mm (Adell et al., 1986; S. W. Yi et al., 2001; Martens et al., 2014; Tallarico et al., 2016; Li et al., 2017; Windael et al., 2018). No difference was noted between the straight versus tilted implants (0.9 mm vs. 0.9 mm, respectively; Li et al., 2017).

Retrospective studies. None of the included retrospective studies reported on radiographic outcomes.

Removable full-arch implant-supported prostheses

Prospective studies. Throughout the mean follow-up period of 2 years, the mean MBL ranged from 1.0 to 1.5 mm, with no difference observed between short (6 mm) versus long implants (>6 mm; Van Assche et al., 2012).

Retrospective studies. After a follow-up period of 1 year, the mean MBL ranged from 0.3 to 0.8 mm, and it amounted to a mean MBL of 1.2 mm after 8 years (Zou et al., 2013).

3.7.2 | Survival of restorations and technical complications

Fixed full-arch implant-supported prostheses

Across the six studies, restoration survival rates ranged from 51.5% (Barootchi et al., 2020) to 100% (S. W. Yi et al., 2001; Tallarico et al., 2016; Cercadillo-Ibarguren et al., 2017; Li et al., 2017; Windael et al., 2018; Barootchi et al., 2020). Technical complications such as fracture of veneering material/teeth, fracture of single/multiple teeth, and screw-loosening were reported in five studies (Supplement 5b; S. W. Yi et al., 2001; Tallarico et al., 2016; Cercadillo-Ibarguren et al., 2017; Li et al., 2017; Barootchi et al., 2020).

Removable full-arch implant-supported prostheses

Survival of the overdentures ranged between 96% (Eccellente et al., 2011) and 100% (Van Assche et al., 2012; Zou et al., 2013). Reported technical complications included abutment/screw-loosening, partial/complete denture fracture, and need of re-lining/adaptation (Supplement 5c).

3.8 | Patient-reported outcomes

3.8.1 | Fixed full-arch implant-supported prostheses

None of the studies reported on PROMs.

3.8.2 | Removable full-arch implant-supported prostheses

Two studies that enrolled patients with maxillary overdentures reported on PROMs (Eccellente et al., 2011; Zou et al., 2013). Patient satisfaction was evaluated by employing questionnaires containing different scalers (i.e., operative and post-operative phase, prosthetic stability, function, speech, aesthetics, hygiene; see Supplement 5). Forty-seven to 100% of the patients were fully satisfied with the phonetic properties; patient satisfaction with function ranged from 58% to 100%; and 37%–100% of the patients were fully satisfied with the aesthetics (Supplement 5).

3.9 | Economic aspects

None of the included studies reported on economic aspects related to fixed and removable full-arch implant-supported prostheses.

3.10 | Risk of bias within studies

The included RCT had an unclear risk of bias overall because of the potential bias in allocation concealment (Domain 2) as well as the potential bias in measurement of outcomes (Domain 4) (Tallarico et al., 2016) (Supplement 1a).

Nine out of 10 non-randomized studies had an overall serious risk of bias (Adell et al., 1986; S. W. Yi et al., 2001; Eccellente et al., 2011; Van Assche et al., 2012; Martens et al., 2014; Cercadillo-Ibarguren et al., 2017; Li et al., 2017; Windael et al., 2018; Barootchi et al., 2020), whereas 1 study was judged to have an overall critical risk of bias (Zou et al., 2013). Bias due to confounding and bias in measurement of outcomes were the most critical domains that were judged to have serious risk in 100% and 70% of the studies, respectively.

4 | DISCUSSION

The present systematic review evaluated the efficacy of various rehabilitation types with fixed or removable full-arch implant-supported prosthesis designs in edentulous patients, with tooth loss mainly due to periodontitis. Eight studies reported on the efficacy of fixed full-arch implant-supported reconstructions, and three studies addressed the outcomes of removable complete implant-supported prostheses. None of the included studies compared dental implant outcomes supporting fixed restorations to those supporting removable restorations.

It is important to highlight the considerable inconsistency among the included studies regarding the definition of the patients' periodontal status or reason for tooth loss. In particular, in two of the included studies, periodontitis was indicated as a reason for edentulism in 39%–44% of the enrolled population. In the other nine studies, periodontitis was mentioned either as one of the reasons for tooth loss ($n = 3$ studies) or as a reason for patients' edentulism ($n = 6$ studies) without providing a clear definition of the disease. In addition, the lack of information on the reason for tooth loss and the patients' periodontal history was among the major reasons for the studies' exclusion from the present analysis ($n = 73$ studies).

The estimations of the present data suggested comparable cumulative implant losses within 1 year for both fixed and removable prosthesis designs (0.64% and 0.71%, respectively). However, cumulative implant loss within 5 years of follow-up was higher for removable prosthesis designs relative to those supporting removable reconstructions (4.45% vs. 1.85%, respectively). The present finding considering different prosthesis designs corroborates a previous meta-analysis that indicated a higher implant-loss rate for implants supporting removable versus fixed full-arch prostheses (0.35 vs. 0.23, respectively; $p = .0148$; Kern et al., 2016). The latter findings align with those of an earlier systematic review based on longitudinal studies of at least 5 years, which reported implant loss in about 2%–3% of implants supporting fixed reconstruction and >5% for the implants supporting overdentures (Berglundh et al., 2002). However, it should be noted that the status of the patients' periodontal health was not considered in the aforementioned analyses (Berglundh et al., 2002; Kern et al., 2016).

A further tendency observed in the present analysis pointed to higher implant loss rates for both prostheses designs within the 5-year compared to the 1-year period. This observation confirms the findings of previous studies that enrolled either patients with fixed full-arch implant-supported prostheses (Chrcanovic et al., 2020) or patients with different prostheses designs (i.e., fully and partially edentulous patients) (Derks & Tomasi, 2015) and reported on higher late implant loss rates (i.e., following the connection of the superstructure) compared to early implant loss (i.e., prior to the functional load). On the other hand, this latter observation contradicts the results of an earlier retrospective study pointing to higher early implant loss (i.e., prior to a 1-year follow-up) compared to implant loss throughout the 5-year period (1 year: 8.1% of implants in the upper jaw, 3.7% of implants in the lower jaw; 5 years: 2.1% of implants in the upper jaw, 0.9% of implants in the lower jaw) (Jemt et al., 2014). This contradiction might be attributable at least partially to the fact that early implant loss included cases of osseointegration failure, which might have contributed to the higher implant during the 1-year follow-up period (Jemt et al., 2014). In the present analysis, except for studies (Eccellente et al., 2011; Van Assche et al., 2012) that reported on implant loss due to osseointegration failure, the remaining studies did not specify the time of implant loss. In addition, as noted above, no previous studies specified patients' periodontal health or the reason for their edentulism (Jemt et al., 2014; Derks & Tomasi, 2015; Chrcanovic et al., 2020). When interpreting the findings of the present analysis, it is worth highlighting the limited number of clinical studies feasible for the analysis (removable prostheses: three studies; fixed prostheses: eight studies) that had either short (i.e., <5 years; (Adell et al., 1986; S. W. Yi et al., 2001; Eccellente et al., 2011; Van Assche et al., 2012) or medium follow-up periods (i.e., 5–10 years; (Zou et al., 2013; Martens et al., 2014; Tallarico et al., 2016; Cercadillo-Ibarguren et al., 2017; Li et al., 2017; Windael et al., 2018; Barootchi et al., 2020), which did not allow assessment of implant losses in the long term.

In the majority of the studies in the present analysis (five reporting on fixed prosthesis and two on removable prostheses), implants were loaded following a delayed protocol, and in one study reporting on fixed prosthesis designs, implants were loaded immediately following the tooth extraction (Li et al., 2017). The remaining three studies (two reporting on fixed prosthesis designs and one on removable prosthesis) employed both immediate and delayed loading protocols (Eccellente et al., 2011; Cercadillo-Ibarguren et al., 2017; Barootchi et al., 2020). As suggested by the previous meta-analyses, for the fixed full-arch restorations, similar implant survival rates were noted regardless of the loading protocol (i.e., immediate, early, and conventional) (Papaspyridakos et al., 2014; Daudt Polido et al., 2018; Gallardo et al., 2019). For removable implant-supported complete prostheses, in contrast, a former meta-analysis pointed towards a tendency for higher implant loss for the immediately loaded implants, supporting the conventional loading protocol (Schimmel et al., 2014). As for the number of implants supporting fixed full-arch prostheses, in the present analysis the number of implants supporting lower and upper full-arch prostheses and fixed and removable prostheses ranged from 4 to 8. Based on the previous findings, similar implant and prosthesis survival rates were reported for fixed prostheses supported by fewer than five or more than five implants per arch in both upper and lower jaws (Daudt Polido et al., 2018). On the other hand, another meta-analysis found a significantly higher implant loss for removable upper and lower jaw prostheses supported by less than four implants (Kern et al., 2016). Similarly, as recent data indicate, an implant-supported fixed and removable prostheses in the edentulous upper jaw, as well as a fixed prostheses in the edentulous lower jaw, should be supported by no fewer than four implants (Messias et al., 2021; Tsigarida & Chochlidakis, 2021). In addition, different implant loss rates were addressed in the upper and lower edentulous jaws, with higher implant loss noted for implants supporting a full-arch prosthesis in the upper jaw (Kern et al., 2016; Chrcanovic et al., 2020). Again, it should be noted that none of the previous analyses referred to periodontitis patients, which, in turn, prevents direct comparison between the present and previous findings (Kern et al., 2016; Daudt Polido et al., 2018; Chrcanovic et al., 2020; Messias et al., 2021; Tsigarida & Chochlidakis, 2021). Given the limited available data in the current study, it was not possible to assess whether factors such as loading protocol and the number of implants per arch in the upper and lower jaw have any influence on the implant survival in patients who lost their teeth due to stage IV periodontitis with full-arch implant-supported restorations. However, as suggested by the recent analysis, based on the similar clinical performance of fixed and removable full-arch prostheses, in cases where both treatment options are feasible, patient expectations and cost should be the determining factors for treatment modality selection (Tsigarida & Chochlidakis, 2021).

Owing to the inconsistency of outcomes reported in the included studies, meta-analysis was not possible for any of the assessed clinical and radiographic outcomes. Nevertheless, the descriptive analysis pointed to a greater range of mean BOP scores reported for fixed prosthesis designs when compared with removable restorations (28%–80% and 27%–28%, respectively). This observation partly aligns with the results of a comparative study which observed a significantly higher increase in PI and BI over a 1-year period for fixed prosthesis designs compared to removable full-arch implant-supported prostheses (ElSyad et al., 2019). The latter tendency was attributed to impeded oral hygiene measures related to fixed prosthesis designs (ElSyad et al., 2019). This assumption aligns with the patients' reported perceptions, according to which the evaluation of accessibility to oral hygiene favoured removable bar-retained overdentures compared to fixed prostheses (Brennan et al., 2010). Further descriptive data of the present analysis revealed a slightly higher range of mean PD and MBL values for fixed prostheses relative to removable ones (2.4–3.73 mm and 0.22–1.71 mm vs. 3.2–3.5 mm and 1.0–1.5 mm, respectively). With regard to the PD values, the aforementioned comparative study reported significantly higher PDs at dental implants supporting fixed prostheses compared to those supporting removable ones (ElSyad et al., 2019). In one earlier analysis, MBL was found to be comparable between removable and fixed prosthesis designs over an investigation period of 4 years (removable range: 0.36–1.5 mm, fixed range: 0.56–1.4 mm; (Saravi et al., 2020). Nonetheless, the aforementioned clinical studies did not specify the reasons for patients' edentulism (ElSyad et al., 2019; Saravi et al., 2020). Therefore, the comparisons of clinical outcomes between the present analysis and previous studies should be interpreted with caution.

Upon further analysis of the current findings, seven studies reported the prevalence of peri-implantitis among fixed full-arch implant-supported prosthesis designs (S. W. Yi et al., 2001; Martens et al., 2014; Tallarico et al., 2016; Cercadillo-Ibarguren et al., 2017; Li et al., 2017; Windael et al., 2018; Barootchi et al., 2020). Accordingly, over a 1–9-year period, peri-implant mucositis and peri-implantitis were detected in 0%–50% and 10%–50% of patients, respectively. The large range of reported disease frequencies may be at least partially attributable to the considerable diversity in the definitions applied to the pathologies. For instance, the MBL cut-off values used to define peri-implantitis ranged between >1.5 and >2.1 mm, whereas two analyses provided no clear case definitions. As the reported prevalence of the disease has been revealed to be highly influenced by the definitions used to define the pathology, the aforementioned findings must be interpreted with caution (Derks & Tomasi, 2015). Furthermore, since only one study reported on the occurrence of peri-implantitis for removable prostheses without providing a case definition, rendering a comparison of the frequency of peri-implant diseases in terms of prosthesis design was not feasible. Nonetheless, a recent systematic review noted a tendency towards higher peri-implantitis frequency among implant-supported overdentures at the patient and implant levels, as compared to fixed full-arch restorations (Ramanauskaite et al., 2021). Although abundant existing clinical data have identified periodontitis and a history of periodontitis as factors that increase the risk of biological implant complications (Karoussis et al., 2003; Canullo et al., 2016; Derks et al., 2016; Rokn et al., 2017; Schwarz et al., 2017), the prevalence of peri-implant diseases in the present analysis is within the range of previously reported data for patient samples not specifying patients' periodontal status (Derks et al., 2016; Vignoletti et al., 2019; Wada et al., 2019).

Based on the present analysis, the reported prosthesis survival rate for fixed restorations ranged from 51.7% to 100% within a 1- to 10-year follow-up period and was 100% for removable prostheses. The latter finding corroborates previously reported outcomes for both removable and fixed full-arch implant-supported reconstructions (Kuoppala et al., 2012; Priest et al., 2014; Chrcanovic et al., 2020; Papaspyridakos et al., 2020). The higher range of prosthesis survival reported for fixed restorations was mainly related to the relatively high framework fracture rates for metal–acrylic hybrid prostheses (Barootchi et al., 2020). In line with previously reported data, complications such as chipping or fracturing of the veneering material and loosening of the abutment screw were the most frequently reported problems related to the fixed reconstruction (Priest et al., 2014; Chrcanovic et al., 2020; Papaspyridakos et al., 2020; Karasan et al., 2021). For removable reconstruction, abutment/screw-loosening, partial/complete denture fracture, and need for relining/adaptation were the main technical problems (Kuoppala et al., 2012; Priest et al., 2014; Karasan et al., 2021). In fact, one systematic review reported a higher incidence of technical complications related to implant components and suprastructures for overdentures than was found in fixed reconstructions (Berglundh et al., 2002). However, the lack of comparative studies in the present analysis did not allow for any comparison of prosthesis survival or technical complications between fixed and removable full-arch implant-supported prostheses for patients with tooth loss mainly due to stage IV periodontitis.

Two studies in the present analysis assessed PROMs for removable full-arch implant-supported prostheses. The proportion of satisfied patients with improvements in function and phonetics following the insertion of implant-supported full-arch maxillary overdentures ranged from 47% to 100%. The range of patients who were completely satisfied with the aesthetics was even greater 36%–100%. Conducting a quantitative analysis was impossible due to the limited number of studies reporting on PROMs and the variety of parameters employed to measure the respective outcomes. Furthermore, because no included studies documented PROMs for fixed full-arch restorations, a comparison of the improvements in patient satisfaction levels in terms of prosthesis design was not feasible. In fact, the aforementioned findings correspond to the conclusions of a previous systematic review on the topic and imply the need for standardized PROMs in future clinical investigations (Yao et al., 2018).

The vast inconsistencies in the reporting of clinical outcomes prevented us from conducting comparative analyses for any of the assessed clinical and radiographic outcomes with respect to different prosthesis designs (i.e., fixed vs. removable). Furthermore, all but one of the included studies were judged to have a high or unclear risk of bias, which may have contributed to the substantial heterogeneity detected among the studies. Assessing publication bias in meta-analyses of prevalence (observational studies) has also been critically appraised, because publication bias is usually a result of undesirable outcomes in comparative studies (Maulik et al., 2011). Other aspects likely to have influenced the outcomes were the pooling of short- and medium-term follow-up data in the meta-analysis and the lack of information on the patients' compliance with supportive therapy in the majority of the included studies, as a lack of or poor adherence to peri-implant maintenance therapy was shown to be a critical aspect in maintaining peri-implant tissue health over time (Ramanauskaite & Tervonen, 2016). Ultimately, the absence of a manual literature search and of grey literature may have constituted a source of publication bias by preventing the identification of relevant articles suitable for inclusion.

The findings of the present analysis suggest the following:

- Considerable inconsistencies exist among studies in reporting patients' periodontal status.
- Cumulative implant loss at 1 year was low in both groups. The validity of data representing 1 year, however, is questionable.
- Cumulative implant loss over 5 years was higher in the removable prosthesis group than in the fixed prosthesis group.
- Data on the occurrence of peri-implantitis were scarce in studies on removable prosthesis. For fixed reconstructions, a large variation on the prevalence of peri-implantitis was reported.
- Scarce clinical data exist on prevalence of peri-implant diseases for removable full-arch implant-supported prosthetic designs.
- There is only limited available data on PROMs and economical aspects.

5 | CONCLUSIONS

Based on the limited low-quality data that were identified, the present analysis pointed to a low and similar cumulative implant loss within 1 year for patients with tooth loss mainly due to stage IV periodontitis restored with either removable or fixed implant-supported full-arch prosthesis. At 5 years of functioning, there was a tendency for better outcomes using fixed designs. Further long-term comparative clinical studies reporting on patients' periodontal condition and the main reasons for tooth loss/tooth extractions are needed to validate the present findings.

CONFLICT OF INTEREST

The authors declare no conflict of interests.

AUTHOR CONTRIBUTIONS

Ausra Ramanauskaite: conception, design, literature search and analysis, interpretation, and manuscript writing; Kathrin Becker: contributed to data analysis and interpretation; Stefan Wolfart: data interpretation and critical revision of the article; Fanya Lukman: literature search; Frank Schwarz: conception, design, data analysis, interpretation, manuscript writing, and critical revision of the article.

DATA AVAILABILITY STATEMENT

Data available on request due to privacy/ethical restrictions.

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