

SYSTEMATIC REVIEW

Efficacy of rehabilitation of stage IV periodontitis patients with full-arch fixed prostheses: Tooth-supported versus Implant-supported—A systematic review

Cristiano Tomasi¹  | Jean-Pierre Albouy² | Dennis Schaller¹ |
Renata Camino Navarro² | Jan Derks¹ 

¹Department of Periodontology, Institute of Odontology, The Sahlgrenska Academy at University of Gothenburg, Gothenburg, Sweden

²Division of Comprehensive Oral Health, Department of Prosthodontics, Adams School of Dentistry, University of North Carolina, Chapel Hill, North Carolina, USA

Correspondence

Cristiano Tomasi, Department of Periodontology, Institute of Odontology, The Sahlgrenska Academy at University of Gothenburg, Box 450, SE 405 30 Gothenburg, Sweden.

Email: cristiano.tomasi@odontologi.gu.se

Abstract

Objectives: To evaluate the efficacy of implant-supported in comparison to tooth-supported full-arch prostheses in patients with stage IV periodontitis.

Materials and Methods: Systematic electronic search (CENTRAL/MEDLINE/SCOPUS) up to March 2020 was conducted to identify randomized controlled trials and cohort-like studies comparing/evaluating fixed full-arch rehabilitation on teeth or implants in patients with stage IV periodontitis. The primary outcome measure was loss of teeth/implants and restorations. Data extraction was performed to create evidence tables, and meta-analyses were carried out as appropriate.

Results: A total of 26 studies (31 publications) were identified but none addressed the scientific question in a controlled and randomized design. The risk of bias throughout the included studies was judged to be high, and meta-analyses demonstrated a high degree of heterogeneity. Mean-weighted observation periods in studies on tooth-supported restorations were significantly longer than in studies on implant-supported restorations. The predicted loss of teeth and tooth-supported full-arch restorations over 10 years was 1% and 5%, respectively. The 15-year estimates were 10% and 13%. Corresponding predictions for implants and implant-supported restorations for 10 years amounted to 4% and 6%, respectively. Technical complications were the most commonly reported and affected 8% of tooth-supported restorations (during 7.2 years) and 42% of implant-supported structures (during 2.6 years). Peri-implantitis- or peri-implantitis-like symptoms were observed at an estimated 9% of implants (after 3.1 years).

Conclusions: Based on observational studies on full-arch rehabilitation of stage IV periodontitis patients, 10-year estimates of tooth loss were lower than the corresponding estimates for implants. Estimated loss of tooth- and implant-supported restorations at 10 years was similar. Technical complications were more prevalent at implant-supported when compared to tooth-supported restorations.

KEYWORDS

full-arch, implant, periodontal disease, rehabilitation, tooth-supported

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1 | INTRODUCTION

The 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions used severity, complexity, and extent of periodontitis to develop four stages (I, II, III, and IV) for disease classification. Furthermore, the grading (A, B, C) was suggested to describe individual disease susceptibility and risk for progression of disease (Papapanou et al., 2018). The key feature of stage IV periodontitis is the need for complex restorative therapy with the aim to stabilize and/or restore function and aesthetics. Fixed restorative therapy for such periodontally compromised patients commonly encompasses two options: one is the preservation of strategically positioned teeth to implement tooth-supported full-arch fixed dental prostheses (Yi et al., 1995), and the other is the extraction of all remaining teeth and subsequent insertion of implants and implant-supported full-arch restorations (Adell et al., 1986). A third option, much less common, is the combined use of teeth and implants to support full-arch dental prostheses (Guarnieri & Ippoliti, 2019).

Extensive tooth-supported fixed bridges on teeth with reduced periodontal support have been used as a treatment option for many decades. Nyman and Lindhe (1976) were among the first to describe an integrated periodontal and prosthetic treatment concept in patients diagnosed with advanced forms of periodontitis. Scientific documentation of this approach originated, for the most part, from Scandinavia and dates back to the 1970s and 1980s. Outcomes were generally described as positive, with estimated 5- and 10-year survival rates for restorations of 96% and 93%, respectively (Lulic et al., 2007).

The introduction of implants as prosthetic abutments expanded treatment options for edentulous patients and for patients with terminal dentition. In fact, implant therapy was initially documented in edentulous patients (Adell et al., 1986; Zarb & Schmitt, 1990, 1991), demonstrating overall favourable outcomes. Three decades later, a systematic review on the ideal number of implants used in edentulous jaws (Daudt Polido et al., 2018) identified almost 100 relevant studies, collectively indicating an implant survival of 96% over a median observation period of 8 years.

The decision to maintain or extract teeth in patients with advanced loss of attachment due to periodontitis is complex. Any restorative success also depends on patient variables, costs analyses, and management of abutments over the patient's lifespan (Lundgren et al., 2008). The aim of the present systematic review was to develop a critical understanding of the efficacy of implant-supported full-arch prostheses in comparison to tooth-supported full-arch prostheses in patients with stage IV periodontitis. The following PICOS were addressed:

1.1 | PICOS question 1

In patients with a periodontally compromised dentition (due to stage IV periodontitis or equivalent), what is the evidence from controlled studies with a minimum follow-up of 1 year that implant-supported full-arch fixed prostheses are more efficacious than tooth-supported full-arch fixed prostheses in terms of survival (of restorations and supportive units) and complications?

1.2 | PICOS question 2

In patients with a periodontally compromised dentition (due to stage IV periodontitis or equivalent), what is the performance of tooth-supported full-arch fixed prostheses as reported in interventional or observational studies with a minimum follow-up of 1 year?

1.3 | PICOS question 3

In patients with a periodontally compromised dentition (due to stage IV periodontitis or equivalent), what is the performance of implant-supported full-arch fixed prostheses following extraction of the remaining teeth as reported in interventional or observational studies with a minimum follow-up of 1 year?

2 | MATERIALS AND METHODS

The protocol of the present systematic review was registered at PROSPERO (CRD42020177086). Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guidelines were followed in reporting this review (Moher et al., 2009). A PRISMA checklist is attached (Appendix S1).

2.1 | Eligibility criteria

Studies reporting on full-arch fixed restorative therapy on ≥ 4 supporting units were eligible for inclusion in the review if they included individuals from 18 years onward suffering from periodontitis stage IV (or equivalent). Studies including initially edentulous subjects were also considered if edentulism was primarily due to advanced periodontitis. Interventions and comparisons eligible for inclusion varied according to the PICOS question. For PICOS question 1, studies should have compared the efficacy of full-arch fixed restorations supported by implants with those supported by teeth with reduced periodontal support (randomized controlled trials). For PICOS questions 2 and 3, longitudinal studies (retrospective and prospective cohort-like studies) with one or multiple arms evaluating the performance of tooth-supported and/or implant-supported full-arch fixed restorations were considered. Studies should have reported (i) survival/loss of restorations, (ii) survival/loss of supporting units, (iii) biological and technical complications, (iv) patient-reported outcomes, and/or (v) health economic variables. The minimum period of follow-up was set to 1 year following prosthesis delivery, and the minimum number of included subjects was 10. Study samples should include $>50\%$ of patients with periodontitis stage IV (or equivalent). Because of time constraints, only articles published in English were considered.

Studies were excluded if no evidence of periodontitis stage IV (or equivalent) was provided and/or edentulism was primarily due to other reasons than periodontitis. Removable restorations were not allowed. Studies including patients provided with zygomatic implants

TABLE 1 Search strategy used for MEDLINE (PubMed), Limits: English, Date: 13 March 2020

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((((full arch [tiab] OR full arches [tiab] OR full jaw [tiab] OR full jaws
[tiab] OR edentulous [tiab]) AND (restoration [tiab] OR restorations
[tiab] OR fixed [tiab] OR bridge [tiab] OR bridges [tiab] OR
bridgework [tiab])) AND (teeth [tiab] OR tooth [tiab] OR implant
[tiab] OR implants [tiab]))) NOT review[tiab] NOT ((animals[mh]
NOT (animals[mh] AND humans[mh]))

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and/or patients who underwent advanced maxillofacial procedures (e.g., iliac crest graft, calvarial graft) were disregarded.

2.2 | Search methods

Electronic databases searched up to 13 March 2020 included Cochrane Central Register of Controlled Trials (CENTRAL), MEDLINE (PubMed), and SCOPUS. Hand-search of bibliographies of previously published reviews was also performed. Search results from all databases were combined and duplicates removed. The search strategy for MEDLINE (PubMed) is outlined in Table 1 as an example.

2.3 | Study selection

Following initial calibration meetings, titles and abstracts of the first 136 electronically identified articles were screened independently by all five reviewers. Kappa statistic was used to assess reviewer agreement. Screening of the remaining reports was then completed separately, applying the inclusion/exclusion criteria and using the Rayyan tool (Ouzzani et al., 2016). Full-text reports were obtained and assessed for studies appearing to meet the inclusion criteria or with insufficient information in the title or abstract to confirm eligibility for inclusion. Disagreement following full-text screening was resolved by discussion.

2.4 | Data management

Two reviewers (DS and RCN) independently extracted data from included articles into evidence tables. Data pertaining to study characteristics such as population, case definition of advanced periodontitis, intervention, comparison, time of follow-up, outcomes reported, and study results/conclusions were considered. All data were reviewed to consider appropriateness for further analysis and entered into a dedicated software program (Prometa3, InterNovi, Freeware, Cesena, Italy).

2.5 | Outcome measures

The primary outcome measure was loss of teeth/implants and restorations. Secondary outcome variables included the occurrence of biological

and technical complications and periodontal/peri-implant parameters (probing depth, bleeding/suppurative on probing, plaque scores). For tooth-supported restorations caries, endodontic lesions, progression of periodontitis, loss of retention, framework fractures, and veneer chipping were considered. For implant-supported restorations, peri-implantitis, bone loss, loss of retention, framework fractures, and veneer chipping were registered. Patient-reported outcome measures (PROMs) and health economic variables were also noted together, with adverse events.

2.6 | Risk-of-bias assessment

Assessment of risk of bias of all included studies was carried out at the time of data extraction using the ROBINS-I tool for evaluation of bias in non-randomized (cohort-like) studies of interventions (Sterne et al., 2016). Results of the grading according to five domains were illustrated using the robvis tool (McGuinness & Higgins, 2020).

2.7 | Data synthesis

No meta-analyses could be performed for PICOS question 1 owing to the lack of relevant studies. For PICOS questions 2 and 3, reported occurrence of loss and complications were pooled using a random-effect model (DerSimonian & Laird, 1986). Weighted estimates of proportions were calculated and expressed through a log function of proportions, resulting in weighted effect sizes with 95% confidence intervals (95% CI). Time of follow-up was used as a moderator in subsequent meta-regression analyses, and linear models of the meta-regression were used to predict outcomes (as log functions). We used the inverse log function to calculate predicted outcomes for different time points. To further describe expected outcomes over the weighted mean observation periods, prediction intervals (IntHout et al., 2016; Borenstein et al., 2017) were added. Statistical heterogeneity among studies was explored by the I^2 index (Higgins et al., 2003). Potential small-study effect and publication bias were analysed by Egger's test (Egger et al., 1997) and illustrated through funnel plots. Sensitivity analysis was performed using the leave-one-out method. All analyses were performed with Prometa3 (InterNovi, Freeware, Cesena, Italy).

3 | RESULTS

3.1 | Search and screening

The combined number of references obtained from the electronic search strategy customized for each database was 2850 citations. Independent screening of titles and abstracts and the addition of 18 citations identified through hand-searching resulted in 403 full-text articles to be retrieved. Kappa scores calculated for screening agreement among the five investigators were ≥ 0.63 . Upon analysis of full texts, 31 articles describing 26 studies were included in the

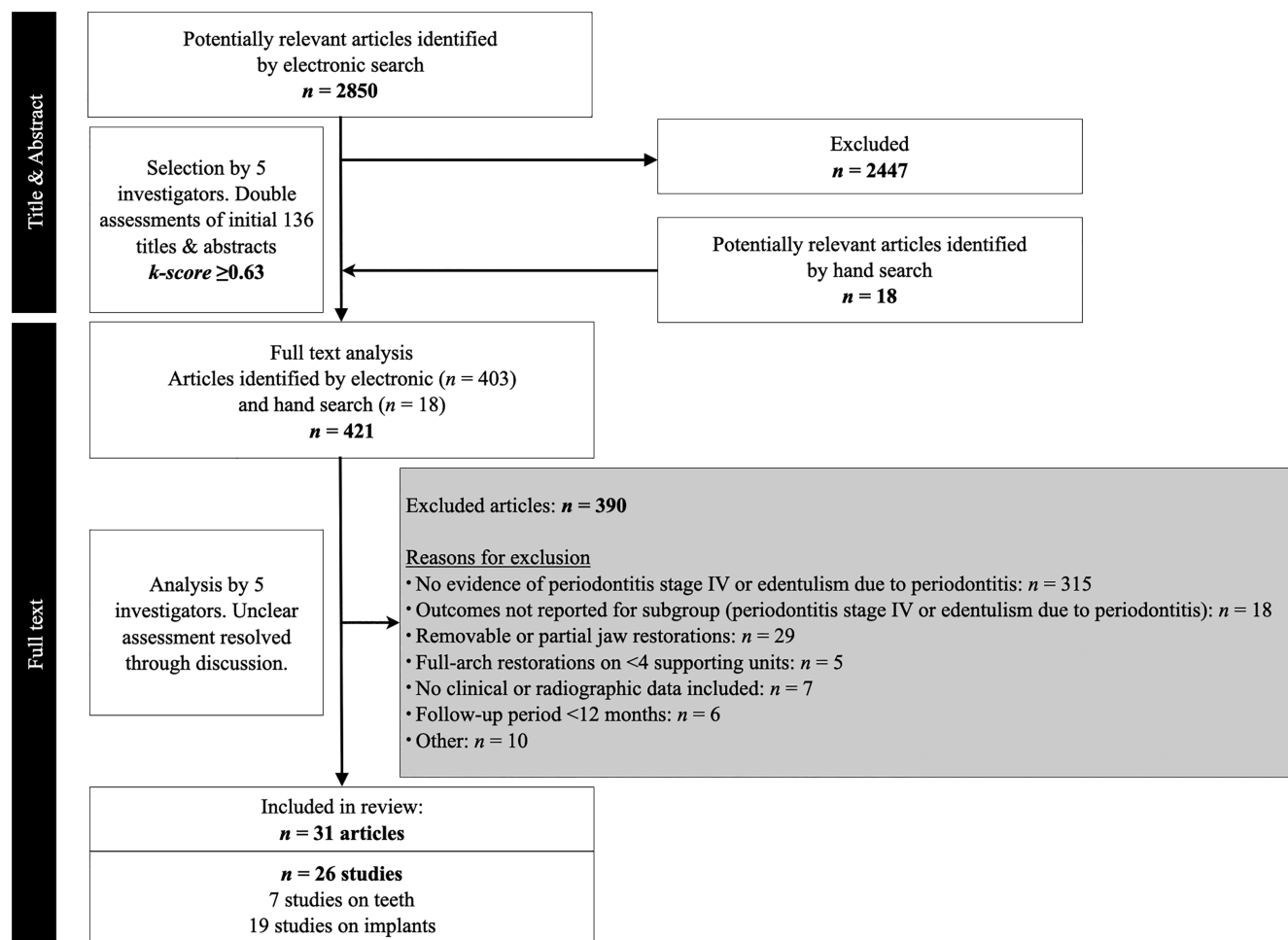


FIGURE 1 Search results illustrated in PRISMA flowchart

review. Figure 1 (PRISMA flow diagram) summarizes the screening results showing the number of citations at each step of the screening process. Following full-text screening, the most common reason for exclusion was the lack of evidence of periodontitis stage IV (or equivalent) or lack of documentation of edentulism being due to periodontitis ($n = 315$). See Figure 1 and Table S1 for details.

3.2 | Descriptive results

Characteristics of and results reported in the included studies are illustrated in Tables 2 and 3. Year of publication ranged from 1975 to 2020, and all but one (Tallarico et al., 2016) were characterized as case series or cohort studies.

3.3 | Risk of bias

Summarized results of the assessment of risk of bias are illustrated in Figure 2. All included studies were judged to present with serious risk of bias, mainly related to potential bias due to confounding (Domain 1) and to potential bias in measurement of outcome (Domain 6).

3.4 | PICOS question 1

None of the included studies addressed PICOS question 1.

3.5 | PICOS question 2

Seven studies (Nyman et al., 1975; Nyman & Lindhe, 1979; Bergenholtz & Nyman, 1984; Laurell et al., 1991; Yi et al., 1995; Fardal & Linden, 2010; Guarnieri & Ippoliti, 2019) specifically addressed PICOS question 2, that is, the performance of tooth-supported full-arch fixed prostheses in patients with a compromised dentition (due to stage IV periodontitis or equivalent). The majority of these studies were published >30 years ago, and all but one (Guarnieri & Ippoliti, 2019) originated from Scandinavian countries (Table 2). All studies were of retrospective design. Two studies (Fardal & Linden, 2010; Guarnieri & Ippoliti, 2019) included implants in full-arch restorations in a subgroup of patients, but data were analysed and reported collectively. Meta-analyses were possible for (i) tooth loss, (ii) loss of restorations, and (iii) occurrence of technical complications. None of the analyses showed a significant small-study effect (Figure S1).

TABLE 2 Tooth-supported full-arch fixed restorations in patients with periodontitis stage IV (or equivalent): Seven studies/seven articles

Study; Country; Clinical setting; Design; Follow-up	Study sample; n subjects; Case definition of periodontitis	Restorative therapy	Outcomes	Comments
Nyman et al. (1975) Sweden University clinic Retrospective case series 2–6 years	20 patients Mean age: 48.9 years (27–69) “Generalized severe periodontitis.”	26 Full-arch fixed prosthetic rehabilitation 123 abutment teeth • 15 maxillary (1 separated) • 9 mandibular	At/during 6 years PD: not reported PD > 6 mm: 0% PI: not reported BOP: not reported ΔMBL: 0.1 mm Mobility: At all examination degree 1 in 7 patients and degree 2 in 2 patients Other complications: 3 caries	<ul style="list-style-type: none"> Periodontal treatment before prosthetic rehabilitation Maintenance care every 3–6 months Patient-reported outcomes and health economic parameters not reported Funding: not reported
Nyman and Lindhe (1979) Sweden University clinic Retrospective case series 5–8 years Mean 6.2 years	251 patients Mean age: 48.7 (23–72) “Generalized severe periodontitis.” Loss of support ≥ 50%	332 Fixed prosthetic rehabilitation • Group A: 132 cross arch bridges with distal abutments • Group B: 159 cross arch bridges with distal cantilevers (1 or 2) • Group C: 34 bridges of unilateral extension	At/During 8 years PI: Gr. A 0.32 Gr. B 0.39 Gr. C 0.42 GI: Gr. A 0.30 Gr. B 0.42 Gr. C 0.38 PD: Gr. A 2.3 mm Gr. B 2.1 mm Gr. C 2.3 mm ΔCAL: Gr. A 0.3 mm Gr. B 0.1 mm Gr. C 0.2 mm ΔMBL: Gr. A 0.15 mm Gr. B -0.02 mm Gr. C 0.08 mm Mechanical complications: Loss of retention Gr. A 6/132 bridges (4.6%) Gr. B 5/159 bridges (3.2%) Fracture bridgework Gr. A 3/132 bridges (2.3%) Gr. B 3/159 bridges (1.9%) Gr. C 1/34 bridges (2.9%) Fracture abutment teeth (one tooth/bridge) Gr. A 3/132 bridges (2.3%) Gr. B 5/159 bridges (3.2%)	<ul style="list-style-type: none"> Periodontal treatment before prosthetic rehabilitation Maintenance care every 3–6 months A fourth group with no prosthetic treatment was also reported regarding PD and bone loss Clinical measurements recorded in a sub-sample of 50 patients, with 74 bridges Patient-reported outcomes and health economic parameters not reported Funding: not reported
Bergenholtz and Nyman (1984) Sweden University clinic Retrospective case series 4–13 years Mean 8.7 years	52 patients Subgroup of Nyman 1979 Mean age 47.1 (21–68) “Generalized severe periodontitis.”	82 Fixed prosthetic rehabilitation • Group A: 25 cross arch bridges with distal abutments • Group B: 30 cross arch bridges with distal cantilevers (1 or 2) • Group C: 27 bridges of unilateral extension 672 vital teeth followed 179 abutment teeth	At/During 13 years PD: not reported PD > 6 mm: not reported PI: not reported BOP: not reported Endodontic complications: Pulpal necrosis in abutment teeth: 38 (15%) 10 due to caries 4 due to progression of periodontitis	<ul style="list-style-type: none"> Periodontal treatment before prosthetic rehabilitation Maintenance care every 3–6 months Patient-reported outcomes and health economic parameters not reported Funding: not reported
Laurell et al. (1991) Sweden University clinic Retrospective case series 5–12 years Mean 8.4 years	34 patients Age not reported “Generalized severe periodontitis.”	36 Fixed full-arch prosthesis all bridges with cantilever on one (12) or both sides (24)	At/During 12 years Loss of restorations: 1/36 restorations lost due to rapid progression 1/36 technical failure (tooth fracture) Mechanical complications:	<ul style="list-style-type: none"> Periodontal treatment before prosthetic rehabilitation Maintenance care regular Patient-reported outcomes and health

(Continues)

TABLE 2 (Continued)

Study; Country; Clinical setting; Design; Follow-up	Study sample; <i>n</i> subjects; Case definition of periodontitis	Restorative therapy	Outcomes	Comments
			1/36 implants added to support a prosthesis PI : 10.9% PD \geq 4 mm: 2.6 (mean per patient) No radiographic bone loss	economic parameters not reported • Funding: not reported
Yi et al. (1995) Sweden University clinic Retrospective case series 10–25 years Mean 15 years	50 patients randomly selected from 200 (Nyman et al) Mean age: 48.9 (27–69) “Generalized severe periodontitis.”	43 Fixed Prosthesis 23 Maxilla 20 Mandible Number of abutment teeth ranged from 5.3 to 6.3 according to group • Group 1: 12 FPD with bilateral end abutment • Group 2: 14 FPD with unilateral cantilever • Group 3: 17 FPD with bilateral cantilever units	<u>At/During 25 years</u> PI : Gr. 1 mean 6% Gr. 2 mean 4% Gr. 3 mean 6% GI : Gr. 1 mean 6% Gr. 2 mean 1% Gr. 3 mean 4% PD \geq 4 mm: Gr. 1 mean 8% Gr. 2 mean 4% Gr. 3 mean 3% BoP : Gr. 1 mean 4% Gr. 2 mean 5% Gr. 3 mean 4% Loss of teeth/restorations : 21/274 (8%) abutment teeth extracted Gr. 1–9 Gr. 2–6 Gr. 3–6 Reason for extractions: root caries (2 teeth), endodontic complications (7), root fracture (1), fracture of restoration (11) 6 restorations fractured and had to be partially replaced	• Periodontal treatment before prosthetic rehabilitation • Maintenance care regular • 16 patients (Nyman et al) did not agree to participate • Patient-reported outcomes and health economic parameters not reported • Funding: not reported
Fardal and Linden (2010) Norway Private practice Retrospective case series 7–22 years Mean 10.2 years	80 patients Mean age: 50 years (29–69) “All patients referred for periodontal treatment From mild to severe periodontitis” 46 females 34 males 60 (75%) smokers	94 bridges full arch (10 unit) • Group 1: 77 tooth supported/603 abutment teeth • Group 2–17 teeth-implant supported: 82 teeth and 54 implants as abutment Mobility degree 2 in 20% of abutment teeth 31 bridges with cantilever extension	<u>At/During 22 years</u> PD : not reported PD $>$ 6 mm: not reported BOP : not reported Plaque control : good in 20%, moderate in 63% and poor in 18% Loss of teeth : 8/685 abutment teeth lost (7 for caries 1 for endodontic reasons) 6.3% patients lost an abutment tooth (5/80) Mechanical complications : 2 bridges with minor ceramic fracture (2/94) 4 bridges had to be recemented (4/94) 1 bridge partially removed (1/94) 1 bridge removed and redone for fracture of the structure (1/94)	• Periodontal treatment before prosthetic rehabilitation • Prosthetic rehabilitation selected to stabilize mobile teeth • 77 patients complied with maintenance, 3 did not • Outcomes not separated for bridges with implants • Patient-reported outcomes and health economic parameters not reported • Funding: by authors

(Continues)

TABLE 2 (Continued)

Study; Country; Clinical setting; Design; Follow-up	Study sample; n subjects; Case definition of periodontitis	Restorative therapy	Outcomes	Comments
			Periodontitis: 53 (66%) patients required additional periodontal treatment No implant lost Peri-implantitis: 3/17 (17.7%) of patients treated for peri-implantitis	
Guarnieri and Ippoliti (2019) Italy 1 Private practice/ University clinic Retrospective case series 15 years	35 patients Mean age: 49.7 years (± 4.8 years) "All Periodontally compromised" Aggressive/chronic classification 18 males 17 females	35 full arch restorations/2 groups: TRP: Telescopic Retrievable Prosthesis 18 patients 164 implants 233 teeth FP: Fixed-Prosthesis. 17 patients 152 implants 151 teeth	<u>At/During 15 years</u> PD: not reported PD > 6 mm: not reported PI: not reported BOP: not reported Loss of teeth/implants: <ul style="list-style-type: none"> TRP 6/164 implants (3.6%) 19/233 teeth (8.1%) FP 6/152 implants (3.9%) 23/221 teeth (10.4%) Periodontitis: <ul style="list-style-type: none"> TRP 11 teeth extracted due to progression of periodontitis. FP 11 teeth extracted due to progression of periodontitis. 	<ul style="list-style-type: none"> Periodontal treatment before prosthetic rehabilitation Fixed full arch with combination of teeth and implants. Aggressive periodontitis—contributing factor to tooth loss and implant failure No teeth vs. implants statistical comparison for failures Recall 3 to 6 months Patient-reported outcomes and health economic parameters not reported Funding: not reported

Abbreviations: BOP, bleeding on probing; CAL, clinical attachment level; CI, confidence interval; CSR, cumulative survival rate; GI, Gingival Index; MBL, marginal bone level; PD, probing depth; PI, Plaque Index; PROMs, patient-reported outcome measures; REC, soft tissue level; SD, standard deviation; SE, standard error; SUP, suppuration on probing.

Based on three studies (Yi et al., 1995; Fardal & Linden, 2010; Guarnieri & Ippoliti, 2019), tooth loss over a period of 12.7 years was estimated at 4.9% (95% CI 2%; 14%). The prediction interval was large, ranging from 0% to 100%. Predicted tooth loss at 15 years was 9.5% (Table 4a and Figure S1a).

Based on four studies (Nyman & Lindhe, 1979; Laurell et al., 1991; Yi et al., 1995; Fardal & Linden, 2010), loss of restorations over an observation period of 9.7 years was estimated at 4.6% (95% CI 2%; 14%). Also, here the prediction interval was large, ranging from 0% to 100%. Predicted loss of restorations at 15 years was 13.3% (Table 4b and Figure S1b).

Data on technical complications were reported in three studies (Laurell et al., 1991; Nyman & Lindhe, 1979; Fardal & Linden, 2010), observing a variety of different problems. These included loss of retention, fractures of framework and teeth, and veneering (chipping). During an observation period of 7.2 years, the overall occurrence of technical complications at the restoration level was 8.0% (95% CI 6%; 11%) and the prediction interval ranged from 1% to 77% (Table 4c and Figure S1c).

Biological complications were not consistently reported and could not be summarized as an outcome. Data on PROMs, health economic parameters, and adverse events were not reported.

3.6 | PICOS question 3

A total of 19 studies (Adell et al., 1986; Grunder, 2001; Yi, Ericsson, et al., 2001; Horwitz et al., 2007; Malo et al., 2007; Horwitz et al., 2008; Tealdo et al., 2008; Alves et al., 2010; Collaert et al., 2011; Tealdo et al., 2011; Barbier et al., 2012; Horwitz & Machtei, 2012; Malo et al., 2012; Martens et al., 2014; Tealdo et al., 2014; Shigehara et al., 2015; Tallarico et al., 2016; Bechara et al., 2017; Cercadillo-Ibarguren et al., 2017; Li et al., 2017; Niedermaier et al., 2017; Windael et al., 2018; Riemann et al., 2019; Barootchi et al., 2020) specifically addressed PICOS question 3, that is, the performance of implant-supported full-arch fixed prostheses in edentulous patients (due to stage IV periodontitis or equivalent). The majority of these studies ($n = 15$) were of prospective design, and

TABLE 3 Implant-supported full-arch fixed restorations in edentulous patients (due to periodontitis): 19 studies/24 articles

Study; Country; Clinical setting; Design; Follow-up	Study sample; Case definition of periodontitis	Restorative therapy	Outcomes	Comments
Adell et al. (1986) Sweden University clinic Prospective case series 3 years	16 patients Mean age: 53 years “...totally edentulous as a result of tooth loss from destructive periodontal disease.”	95 implants 16 full arch implant-supported restorations. Maxilla: 7 (on 6 implants) Mandible 9 (on 5–6 implants) All restorations were screw-retained.	At/During 3 years Implant loss: 0% ΔMBL: –1.0 mm (mean) PD: 2.9 mm (mean) PD > 6 mm: 0% PI: 25–30% (implants) BOP: 15–20% (implants) Peri-implantitis: Not reported Technical complications: Not reported	<ul style="list-style-type: none"> Periodontal treatment before prosthetic rehabilitation Pre-therapeutic period of edentulism: mean 15.2 years 1 patient excluded from final evaluation No information on maintenance care Patient-reported outcomes and health economic parameters not reported Funding: not reported
Grunder et al. (2001) Switzerland Private practice Prospective case series 1.6 year	8 patients Mean age: 53 years (37–64) “83% extractions due to periodontitis.” 3 males 5 females 5 max et 5 mand. 6 smokers	91 implants 10 full arch implant supported restoration Immediate loading—24 h fixed temporary. PFM in 9 jaws Titanium-acrylic in 1 maxilla.	At/During 1.6 years Implant loss: 7 implants failed in 5 patients CSR: 97% ΔMBL: <ul style="list-style-type: none"> 0–1 mm: 26.2% 1–2 mm: 67.2% 2–3 mm: 5.4% 3–4 mm: 1.2% PD: not reported PD > 6 mm: not reported PI: not reported BOP: not reported Peri-implantitis: not reported Technical complications: Fracture of acrylic resin in temporary restorations 3/10 Overall Success rate 92.31% 87.5% in maxilla 97.6% in mand. Immediately loaded implants Success rate 95.45% 91.43% in the maxilla 100% in the mandible	<ul style="list-style-type: none"> No periodontal treatment before prosthetic rehabilitation Recall every 4 and 6 months—Evaluation at 1 and 2 years. No specific periodontitis classification reported Number of teeth extracted not reported Exact number of patients with periodontal involvement not reported Patient-reported outcomes and health economic parameters not reported Funding: not reported
Yi, Carlsson, et al. (2001) South Korea University clinic Prospective 3 years	43 patients Mean age: 58 years (range not reported) “All patients participating in the trial were referred to the clinic for treatment of advanced periodontal disease.”	125 implants total 6 complete implant-supported fixed prostheses (35 implants)	At/During 1 year complete ISFP subgroup: Implant loss: 0% ΔMBL: 0.22 mm (–1.0 to 1.0) ΔMBL > 0.5 mm: 20% of implants PD > 4 mm: 10–11 implants PD > 6 mm: not reported PI: 2% (implants) BOP: 1% (implants) Peri-implantitis: not reported Technical complications: 3 material fracture/	<ul style="list-style-type: none"> Periodontal treatment before prosthetic rehabilitation No drop outs Clinical parameters unclear (Table 3) Health economic parameters not reported Patient evaluation reported in separate publication (Yi, Carlsson, et al., 2001). Generally high degree of satisfaction. Similar levels of function as

(Continues)

TABLE 3 (Continued)

Study; Country; Clinical setting; Design; Follow-up	Study sample; Case definition of periodontitis	Restorative therapy	Outcomes	Comments
			chipping (porcelain) and 1 (acrylic)	dentate control group. More difficulty in performing oral hygiene procedures. • Funding: not reported
Malo et al. (2007) Portugal Private practice 5 years	Retrospective Group 184 Patients in total Mean Age: 57 years Periodontally compromised: “implants placed in an area or adjacent to a tooth or teeth with periodontitis at the time of surgery.”	433 TOTAL Implants: 140 maxilla/293 in the mandible 218 TOTAL Prosthesis 94 Prosthesis were fixed complete dentures (33 in the maxilla/61 in the mandible). Retrospective Group: 165 implants: 47 maxilla/118mandible 81 patients (35 men and 46 women) Immediate Load Definitive prosthesis were placed 6 months after the surgery	Retrospective Group: 24 FCD—8 maxilla/16 mandible <u>At/During 1 year</u> Implant loss: 13 implants (9 patients) SR: 93% SR Periodontally Compromised: 92.8% SR Post extraction socket: 87.1% SR Systemic Group Factor: 94.2% ΔMBL: 1.2 mm (0.9 mm) PD: not reported PD > 6 mm: not reported PI: not reported BOP: not reported Peri-implantitis: not reported Technical complications: not reported <u>At/During 5 year</u> CSR: 91% Implant loss: 13 implants (9 patients) SR: 73% ΔMBL: 1.7 (1.0) mm PD: not reported PD > 6 mm: not reported PI: not reported BOP: not reported Peri-implantitis: not reported Technical complications: not reported	• No periodontal treatment before prosthetic rehabilitation • All implants were placed immediately in periodontally compromised areas without a healing period • Both groups were then subdivided in 3 groups • Funding: not reported • Retrospective group (using an unstandardized surgical technique and a majority of machined surface implants) • The cumulative survival rate of 91% at 5 years is low compared to protocols for non-compromised situations • Patient-reported outcomes and health economic parameters not reported
	Prospective Group Mean Age: 52 years Periodontally compromised: “implants placed in an area or adjacent to a tooth or teeth with periodontitis at the time of surgery.”	268 implants: 92 maxilla/176 mandible 103 patients (52 men and 51 women)	Prospective Group: 70 FCD—25 maxilla/45 in the mandible <u>At/During 1 year</u> CSR: 100% Implant loss: none SR: 100% ΔMBL: 1.1 (1.1) mm PD: not reported PD > 6 mm: not reported PI: not reported BOP: not reported Peri-implantitis: 1 implant in a diabetic patient in the systemic risk factors subgroup. Technical complications: 3 patients developed screw loosening during	• Prospective group (using standardized surgical and maintenance protocols and oxidized surface implants) • MBL did not differ from the results generally found for implants placed in healed sites and was substantially lower in the “postextraction sockets” subgroup • 1 implant was lost after 3 years of follow-up due to peri-implant pathology in a diabetic

(Continues)

TABLE 3 (Continued)

Study; Country; Clinical setting; Design; Follow-up	Study sample; Case definition of periodontitis	Restorative therapy	Outcomes	Comments
			<p>the healing period—resolved after instructed not to overload</p> <p><u>At/During 5 years</u></p> <p>CSR: 95.5%</p> <p>Implant loss: 1 implant was lost after 3 years</p> <p>SR: 95.5%</p> <p>ΔMBL: −1.1 mm</p> <p>PD: not reported</p> <p>PD > 6 mm: not reported</p> <p>PI: not reported</p> <p>BOP: not reported</p> <p>Peri-implantitis: 13 implants in 7 patients</p> <p>Technical complications: 3 implants in 3 patients—screw loosening (healing period)</p>	<p>patient in the systemic risk factors subgroup.</p> <ul style="list-style-type: none"> The use of a standardized protocol together with oxidized surface implants seemed to improve treatment outcomes and improved survival rates to levels similar to non-compromised situations Patient-reported outcomes and health economic parameters not reported
Tealdo et al. (2008) Italy University clinic Prospective case series mean follow-up 20 months) Analysis of 1-year data	21 patients Mean age: 58 years “Maxillary tooth loss for the patients in this study was attributed to periodontal disease in 11 patients,”	111 implants 21 full arch maxillary fixed prostheses	<p><u>At/During 1 year</u></p> <p>Implant loss: 8 implants (3 months)</p> <p>ΔMBL: mesial: −0.74 mm/ distal: −0.94 mm</p> <p>CSR: 92.8</p> <p>PD: not reported</p> <p>PD > 6 mm: not reported</p> <p>PI: not reported</p> <p>BOP: not reported</p> <p>Peri-implantitis: not reported</p> <p>Technical complications: not reported</p>	<ul style="list-style-type: none"> No periodontal treatment—edentulous patients No clinical data Patient-reported outcomes and health economic parameters not reported Funding: not reported
Alves et al. (2010) Portugal Specialist clinic Prospective case series 3 years	23 patients Age: not reported All patients were “periodontally compromised”.	168 implants 26 full arch implant-supported restorations on 4–10 implants. Maxilla: 12 Mandible 14 Prosthetic loading within 24 hours. Screw-retained: 20 restorations Cemented: 6 restorations	<p><u>At/During 3 years</u></p> <p>Implant loss: 1% (implants)</p> <p>ΔMBL: Not reported</p> <p>PD: Not reported</p> <p>PD > 6 mm: Not reported</p> <p>PI: not reported</p> <p>BOP: Not reported</p> <p>Peri-implantitis: Not reported</p> <p>Technical complications: Not reported</p>	<ul style="list-style-type: none"> No periodontal treatment before prosthetic rehabilitation 108/168 implants were placed immediately post extraction. Maintenance care: 4 visits/year Patient-reported outcomes and health economic parameters not reported Funding: not reported
Barbier et al. (2012) Belgium University Hospital Prospective case series 1.5 years	20 patients Mean age: 61 years (46–87) 69% of tooth extractions due to “...terminal periodontal disease”.	120 implants 20 full arch implant-supported restorations in the maxilla on 6 implants. Prosthetic loading within 24 hours. All restorations were screw-retained.	<p><u>At/During 1.5 years</u></p> <p>Implant loss: 0%</p> <p>ΔMBL: −0.2 mm (mean)</p> <p>Bone loss ≥ 2 mm: 0%</p> <p>PD: Not reported</p> <p>PD > 6 mm: Not reported</p> <p>PI: not reported</p> <p>BOP: Not reported</p> <p>Peri-implantitis: Not reported</p> <p>Technical complications (final bridgework): 0%</p>	<ul style="list-style-type: none"> No periodontal treatment before prosthetic rehabilitation 60/120 implants were placed immediately post extraction. 2 implants excluded from final evaluation. No information on maintenance care Patient-reported outcomes and health economic parameters not reported Funding: not reported

(Continues)

TABLE 3 (Continued)

Study; Country; Clinical setting; Design; Follow-up	Study sample; Case definition of periodontitis	Restorative therapy	Outcomes	Comments
Horwitz and Machtei (2012) Israel University hospital Prospective case series 5 years also reported in: Horwitz et al. (2007, 2008) 1 year	19 patients (5 patients received full-arch restorations). Mean age: 53 years (34–79) All patients were diagnosed with “moderate to severe generalized chronic periodontitis...”. Mean remaining radiographic bone support at remaining teeth: 52% of root length.	35 implants 5 full arch implant-supported restorations on 6–8 implants. Maxilla: 3 Mandible: 2 Immediate prosthetic loading. All final restorations were cemented.	<u>At/During 1 year</u> Implant loss: 31% (implants) ΔMBL: Not reported for full arch restorations Bone loss ≥ 2 mm: Not reported PD: Not reported BOP: Not reported Peri-implantitis: Not reported Technical complications: Not reported <u>At/During 5 years</u> Implant loss: 31% (implants) ΔMBL: Not reported for full arch restorations Bone loss ≥ 2 mm: Not reported for full arch restorations PD: Not reported PI: not reported BOP: Not reported Peri-implantitis: Not reported Technical complications: Not reported	<ul style="list-style-type: none"> Periodontal treatment before prosthetic rehabilitation. 1 patient did not attend the 5-year evaluation. Maintenance care: 2–4 visits/year. 41/74 implants were placed immediately post extraction (not specifically reported for full arch restorations). Patient-reported outcomes and health economic parameters not reported Funding: partly industry
Malo et al. (2012) Portugal Private practice Prospective cohort study 5 years Mean 2 years	142 patients Perio patients: start time 14 patients and at 12 months—11 patients. Mean age: 53.7 years Periodontally compromised—“implants were inserted in areas with periodontitis at the time of the surgery.”	59 implants (perio patients) Maxilla: 32 implants Mandible: 27 implants loaded 2–3 h after surgery Final restoration screw retained (titanium/acrylic or titanium/ceramic)	<u>At/During 1 year (Perio patients)</u> Implant loss: 1 (maxilla) 2 (mandible) CSR: Maxilla 96.9%/Mandible 92.6% ΔMBL: Maxilla: 1.5 mm at 22 implants Mandible: 1.5 mm at 22 implants PD: not reported PD > 6 mm: not reported PI: not reported BOP: not reported Peri-implantitis: 6 implants in 6 patients (3 maxilla and 3 in the mandible) Technical complications: not reported <u>At/During 5 year (Perio patients)</u> ΔMBL: Maxilla: 1.7 mm in 9 implants Mandible: 1.9 in 6 implants PD: not reported PD > 6 mm: not reported PI: not reported BOP: not reported	<ul style="list-style-type: none"> No periodontal treatment before prosthetic rehabilitation Definitive prosthesis was delivered 6 months after surgery Patients were followed between 1 to 107 months (mean 26 months) 7 patients with 13 implants withdrew from the study Higher incidence of withdrawal in the periodontally compromised group was seen in the maxilla (3 patients—9 implants) Drop out rate < 10% per category Seven implants were lost—3 (3 patients maxilla) and 4 (3 patients mandible) CSR implants level: 97.7%—(maxilla) 94.8%—(mandible) Lower survival rates on post extraction sites

(Continues)

TABLE 3 (Continued)

Study; Country; Clinical setting; Design; Follow-up	Study sample; Case definition of periodontitis	Restorative therapy	Outcomes	Comments
			Peri-implantitis: 6 implants in 6 patients (3 maxilla and 3 in the mandible) Technical complications: 6 prosthesis fractured (2 maxilla—4 mandible) all diagnosed with bruxism	and periodontally compromised sites • Patient-reported outcomes and health economic parameters not reported • Funding: not reported
Martens et al. (2014) Belgium Prospective case series Mean 4.7 years	33 patients Mean age: 66 years “All patients classified as periodontally compromised—based on tooth loss at a young age and/or ongoing periodontal disease in remaining teeth.”	163 implants 33 full arch restorations Maxilla: 130 (35 patients) Mandible: 33 (8 patients) Immediately loaded within 72 h	At/During 1 year Implant loss: 6 implants (4 patients) 4.7 years: 9/163 implants failed SR: 96.3% ΔMBL: 1.6 mm PD: 3.4 mm (mean) PD > 6 mm: 5.4% PI: 79.5% (implants) BOP: 70.6% (implants) Peri-implantitis: 6% Technical complications: not reported	• Periodontal treatment before prosthetic rehabilitation • All failure rates were in the maxilla. • Drop out rate 4% • No correlation was found between PD and MBL • Patient-reported outcomes and health economic parameters not reported • Funding: not reported
Tealdo et al. (2014) Italy University clinic Prospective cohort Study 6 years Mean 6.2 years (range 6–7.5 years) previously described in: Tealdo et al. (2011)	49 patients Mean age: 58.2 years “...edentulous maxillae or seriously unfavourable prognoses for their maxillary dentitions...” “The unfavourable prognoses for the maxillary dentitions for patients in this study were attributed to periodontal disease (n = 28)....” Test group: 34 patients postextraction implant placement with immediate loading Control group: 15 patients edentulous ≥3 months prior to implant surgery; transitional complete dentures; delayed loading	163 implants screw-retained fixed maxillary prosthesis 97 implants screw-retained fixed maxillary prosthesis	At/During 6 years Implant loss: 4.1%—4 implants (12 months) CSR: 93.9% ΔMBL: 1.62 ± 1.23 mm PD: not reported PD > 6 mm: PI: not reported BOP: not reported Peri-implantitis: not reported Technical complications: 4 minor veneer fractures/2 major fractures. Loosening prosthetic screw (3) At/During 6 years Implant loss: 6.1% -10 implants (3 months) CSR: 95.9% ΔMBL: 2.44 ± 1.44 mm PD: not reported PD > 6 mm: not reported PI: not reported BOP: not reported Peri-implantitis: not reported Technical complications: 3 minor veneer fractures/1 major fracture Loosening prosthetic screw (5). Prosthodontic success rate: 73.3%	• No periodontal treatment before prosthetic rehabilitation • 2 drop outs (1 test, 1 control) • No implant lost between 36-month and 75.2-month follow-up • prostheses survival rate 100% • Technical complications: 10 veneering fractures, 8 screw loosening • Patient-reported outcomes and health economic parameters not reported • Funding: not reported
Shigehara et al. (2015) Japan Private practice	27 patients Mean age: 61.8 years	189 SLA-implants (Straumann)	At/During 9 years Implant loss: 0 CSR: 100%	• Edentulous patients • No clinical data • No bone level analysis

(Continues)

TABLE 3 (Continued)

Study; Country; Clinical setting; Design; Follow-up	Study sample; Case definition of periodontitis	Restorative therapy	Outcomes	Comments
Retrospective 6.5 years (range 5.3–9.1)	“All patients lost their teeth because of severe periodontal disease or caries.”	28 full arch fixed prosthetic rehabilitation 18 Maxillary 10 Mandibular (1 patient with both jaws restored) Immediately loaded within 24 h	ΔMBL: not reported PD: not reported PD > 6 mm: not reported PI: not reported BOP: not reported Peri-implantitis: not reported Technical complications: not reported	<ul style="list-style-type: none"> • Implant survival 100% • Final prosthesis success 100% • Patient-reported outcomes and health economic parameters not reported • Funding: not reported
Tallarico et al. (2016) Italy Private practice RCT 5 years	40 patients Mean age: 63 years (42–87) “... patients with maxillary edentulism or with failing dentitions...” “Failing dentitions were noted when two or more of the following characteristics were present: loss of more than 75% of supporting bone, probing pocket depths ≥ 8 mm, class III furcation, hypermobility, and nontreatable endodontic issues.” Group 1: All-On-4 20 patients Group 2: All-On-6 20 patients	80 implants (Nobel Biocare) 20 fixed full arch maxillary prostheses Immediately loaded	<u>At/During 5 years</u> Implant loss: 1 (1.25%) ΔMBL: –1.71 mm PD: not reported PD > 6 mm: not reported PI: 20% (16 implants) BOP: 6.3% (3 patients) Peri-implantitis: 3 patients Technical complications: 3 (healing) 3 (definitive) Biological complications: 1 (healing) 1 (definitive)	<ul style="list-style-type: none"> • Patients received professional oral hygiene instructions prior to restorative therapy • No patients lost to follow-up • Radiograph at implant insertion as baseline for marginal bone level changes • Patient-reported outcomes and health economic parameters not reported • Funding: not reported
		120 implants (Nobel Biocare) 20 fixed full arch maxillary prostheses Immediately loaded	<u>At/During 5 years</u> Implant loss: 6 (5.0%) ΔMBL: –1.51 mm PD: not reported PD > 6 mm: not reported PI: 9.2% (11 implants) BOP: 7.5% (5 patients) Peri-implantitis: 2 patients Technical complications: 1 (healing) 1 (definitive) Biological complications: 1 (healing) 2 (definitive)	
Bechara et al. (2017) Lithuania Specialist clinic and University hospital Prospective case series 1–3 years Mean: 2.0 ± 0.8 years	24 patients Mean age: 55 years (34–77) All patients had a “history of periodontitis”.	215 implants 36 full arch implant-supported restorations on 4–8 implants. Maxilla: 21 Mandible 15 Prosthetic loading within 36 hours (27/36 restorations). All restorations were cemented.	<u>At/During 2 years</u> Implant loss: 1% ΔMBL: –0.3 mm (mean) Bone loss ≥ 2 mm: 0% PD: Not reported PI: Not reported BOP: Not reported Peri-implantitis: 0% Technical complications (final bridgework): 8% (patients)	<ul style="list-style-type: none"> • Patients attended a professional hygiene procedure 1 week prior to surgical intervention • 144/215 implants were placed immediately post extraction. • Maintenance care: ≥2 visits/year. • Technical complications occurring in two patients consisted of chipping and/or fracture of ceramics. Repair by dental technician. • Patient-reported outcomes and health

(Continues)

TABLE 3 (Continued)

Study; Country; Clinical setting; Design; Follow-up	Study sample; Case definition of periodontitis	Restorative therapy	Outcomes	Comments
				economic parameters not reported • Funding: not reported
Li et al. (2017) Republic of China University clinic Prospective case series 2–7 years Mean: 5 years	17 patients Mean age: 39 years All patients were defined as “advanced general aggressive periodontitis according to the modified criteria proposed by CDC/AAP (2007)”.	80 implants 20 full arch implant supported restorations Maxilla: 7 Mandible: 13 Loading 6 h after surgery	At/During 5 years Implant loss: 1 implant CSR: 98.75%—(implants) ΔMBL: 0.8 mm PD: 3 mm PI: 1.2 BOP: 0.5 GI: 0.4 Peri-implantitis: 1.3% (implants) Mechanical Complications: 24.9% (definitive restorations) PROMs: 1 patient with initial phonetic problems. Otherwise high satisfaction. At/During 7 years ΔMBL: 1.2 ± 0.5 mm	• No periodontal treatment before prosthetic rehabilitation • 1 implant was removed (4 months after surgery) due to peri-implantitis • Funding: governmental
Cercadillo-Ibarguren et al. (2017) Spain Private practice Retrospective case series 1–9 years Mean 4.1 years	56 patients Mean age: 64 years All patients had a history of periodontal disease 26 men/30 women	72 full arch implant supported restoration 378 implants Maxilla: 40 Mandible: 32 Loading 6–48 h after surgery	At/During 9 years Implant loss: 2 implants (2 patients) SR: 95.5% (implant) ΔMBL: PD: 2.4 mm PD > 6 mm: not reported PI: 1.5 BOP: 215/378 Peri-implantitis: 54/378 Technical complications: No major technical complication	• Periodontal treatment before prosthetic rehabilitation—not specified • Neither the number of implants per arch ($p = 0.489$) nor the time of follow-up ($p = 0.525$) was related to the presence of peri-implantitis • No statistically significant differences were found between gender, bruxism, smoking habit, compliance with maintenance visits, implant angulation, implant placement protocol, arch, prosthetic material, opposing dentition and abutment exposure or abutment height with peri-implantitis • Patient-reported outcomes and health economic parameters not reported • Funding: institutional
Windael et al. (2018) Belgium University clinic Prospective case series 10 years previously described in:	21/25 patients available for 10 years examination (16% drop out) Mean age: 68.4 years “Patients were classified with or without a history	105 implants (60 implants in patients with history of periodontitis) 21 full arch screw-retained mandibular fixed prostheses	At/During 10 years Implant loss: none ΔMBL: 120 m vs. 12 m: 0.36 ± 1.03 mm 10 implants with BL ≥ 2 mm	• Some patients were in active treatment (non-surgical) for periodontal disease. • 2/21 (10%) patients or 5/105 (4.8%) implants

(Continues)

TABLE 3 (Continued)

Study; Country; Clinical setting; Design; Follow-up	Study sample; Case definition of periodontitis	Restorative therapy	Outcomes	Comments
Collaert et al. (2011)	of periodontitis based on the following criteria: (a) radiographic evidence of bone loss extending $\frac{1}{3}$ 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 whereby 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" "Eleven patients lost their teeth due to periodontitis"	Loading 24 h after surgery	PD: 3.77 mm (mean) PD > 6 mm: not reported PI: 67.6% BOP: 49.5% Peri-implantitis: 5 implants (4.8%) Technical complications: not reported 23 implants with PD >4 mm, 4 implants with PD >5 mm implant and prosthesis survival 100% PII 67.6% (implant level)	were diagnosed with peri-implantitis based on bleeding on probing in combination with marginal bone loss exceeding 2 mm. <ul style="list-style-type: none"> Both patients diagnosed with peri-implantitis had a history of periodontitis No significant differences for BL between patients with/without history of periodontitis Abutment height \leq 1.5 mm significant factor for bone loss Patient-reported outcomes and health economic parameters not reported Funding: industry
Riemann et al. (2019) Germany Private practice Retrospective cohort study 1–6.5 years Mean 1.9 ± 1.6 years previously described in: Niedermaier et al. (2017)	380 patients Mean age: 61.9 years "Perio involved in 80.7% of extractions" (as described in Niedermaier et al. (2017))	2081 implants 482 implant-supported fixed full-arch prostheses Loading within 24 h Teeth ($n = 2548$) extracted due to: Periodontitis: 53.5% Endodontic, Periodontitis: 12.6% Caries, Periodontitis: 11.4% Endodontic, Caries, Periodontitis: 3.2%	At/During 6.5 year Implant loss: 42 Δ MBL: ≥ 2 mm: 9.4% of all implants PD: not reported PD > 6 mm: not reported PI: not reported BOP: not reported Technical complications: complete prosthesis failure 0.5% ($n = 2$) Overall complication rate at restoration level: 40%	<ul style="list-style-type: none"> No periodontal treatment before prosthetic rehabilitation 1 drop out (4 implants) Data provided on number of implants in 1–7 year follow-up 16.3% of implants followed up >5 years Patient-reported outcomes and health economic parameters not reported Funding: not reported
Barootchi et al. (2020) United States University clinic Retrospective cohort study 5 years Average follow up period 8.7 ± 3.3 years for all prosthesis. Median follow up of 8 years	56 Patients Mean age: 52.9 History of Periodontal Disease: "Presence of at least 4 sites with CAL > 3 mm and or patients who had received periodontal treatment".	452 implants 74 arches (43 metal acrylic/31 zirconia) Perio patients: 9 (metal acrylic) 13 (zirconia)	At/During 5 year Implant loss: 51 implant CSR: 93.7% (zirconia)/83% metal acrylic Δ MBL: not reported PD: not reported PD > 6 mm: not reported PI: not reported BOP: not reported Peri-implantitis: 95 implants Technical complications: single tooth chipping and multiple teeth or framework fracture Cost analysis: Average cost per single implant per year of follow-up ranged from \$292 to \$485.	<ul style="list-style-type: none"> Periodontal treatment before prosthetic rehabilitation Zirconia restorations had higher survival rate A history of periodontal disease increased the risk of peri-implantitis up to four times (OR: 4.10/P = .003) Patient-reported outcomes not reported Funding: partially institutional

Abbreviations: BOP, bleeding on probing; CAL, clinical attachment level; CI, confidence interval; CSR, cumulative survival rate; GI, gingival index; MBL, marginal bone level; PD, probing depth; PI, plaque index; PROMs, patient-reported outcome measures; REC, soft tissue level; SD, standard deviation; SE, standard error; SUP, suppuration on probing.



FIGURE 2 Individual and summarized assessment of risk of bias for included studies using the robvis tool (McGuinness & Higgins, 2020)

sample sizes ranged from 8 (Grunder, 2001) to 380 (Riemann et al., 2019) subjects. Time of follow-up ranged from 1 to 10 years (Windael et al., 2018) (Table 3). In 15 of the 19 included studies, immediate or early prosthetic loading of implants was performed.

Meta-analyses were possible for (i) loss of implants, (ii) loss of restorations, (iii) occurrence of technical complications, and (iv) occurrence of biological complications (at implant and restoration levels). A significant small-study effect was observed for one of the analyses as indicated by the Egger test (loss of implants; Figure S2).

Based on 15 studies (Adell et al., 1986; Grunder, 2001; Yi, Ericsson, et al., 2001; Malo et al., 2007; Tealdo et al., 2008; Alves et al., 2010; Barbier et al., 2012; Horwitz & Machtei, 2012; Malo et al., 2012; Martens et al., 2014; Tealdo et al., 2014; Tallarico et al., 2016; Bechara et al., 2017; Li et al., 2017; Windael et al., 2018), implant loss over an observation period of 3.9 years was estimated at 3.5% (95% CI 2%; 7%). The prediction interval ranged from 0% to 34%. Predicted implant loss at 10 years was 3.6% (Table 5a and Figure S2a).

Loss of implant-supported full-arch fixed restorations, as reported in nine studies (Grunder, 2001; Yi, Ericsson, et al., 2001; Malo et al., 2012; Tealdo et al., 2014; Shigehara et al., 2015; Tallarico et al., 2016; Windael et al., 2018; Riemann et al., 2019; Barootchi et al., 2020), was estimated to be 4.6% (95% CI 1%; 18%) during an observation period of 3.2 years. The corresponding prediction interval ranged from 0.4% to 100%. The predicted loss of restoration at 10 years was 5.8% (Table 5b and Figure S2b).

Occurrence of technical complications at the restoration level was also analysed based on nine studies (Grunder, 2001; Yi, Ericsson, et al., 2001; Barbier et al., 2012; Malo et al., 2012; Tealdo et al., 2014; Tallarico et al., 2016; Bechara et al., 2017; Li et al., 2017; Riemann et al., 2019) with a collective time of follow-up of 2.6 years. Reported complications included chipping, loss of retention, and fractures of framework. The estimated proportion of restorations affected by at least one such complication was 41.7% (95% CI 25%; 68%). The prediction interval ranged from 9.4% to 100%, and the predicted proportion at 10 years was 76% (Table 5c and Figure S2c).

Biological complications at implant-supported full-arch fixed restorations were addressed at the implant and restoration levels and included peri-implantitis and/or marginal bone loss. At implants, a total of 12 studies (Grunder, 2001; Yi, Ericsson, et al., 2001; Malo et al., 2007; Barbier et al., 2012; Malo et al., 2012; Martens et al., 2014; Bechara et al., 2017; Cercadillo-Ibarguren et al., 2017; Li et al., 2017; Windael et al., 2018; Riemann et al., 2019; Barootchi et al., 2020), covering a time period of 3.1 years, were available. Based on the reported data, 8.5% (95% CI 5%; 13%) of all implants developed at least one biological complication. The predicted proportion for 10 years was 9.5% (Table 5d and Figure S2d). At the restoration level, three studies were available (Tallarico et al., 2016; Bechara et al., 2017; Windael et al., 2018), covering a time period of 4.4 years. An estimated 12.3% (95% CI 4%; 36%) of restorations were affected, and the corresponding estimate for 10 years was 28% (Table 5e and Figure S2e).

TABLE 4 Tooth-supported full-arch fixed prostheses: Loss/complication rates

(a) Loss of teeth							
	Follow-up (years)	Effect size (95% CI)	Variance	Standard error	Events/N	Weight (%)	Sensitivity analysis (overall effect size if study is left out)
Fardal & Linden, 2010	10.2	−4.44 (−5.14; −3.74)	0.13	0.36	8/685	31.13	−2.35
Guarnieri et al., 2019	15.0	−2.28 (−2.60; −1.97)	0.03	0.16	42/454	34.96	−3.44
Yi et al., 1995	15.0	−2.49 (−2.93; −1.97)	0.05	0.23	21/274	33.91	−3.34
Overall (weighted)	12.7	−3.02 (−4.07; −1.98)	0.28	0.53	71/1413		
Prediction interval (for 12.7 years)		4.90% (0.00%; 100.00%)					
I² 93.50; T² 0.79							
Years of follow-up							Predicted failure (%)
5							0.13
10							1.11
15							9.54
(b) Loss of restorations							
	Follow-up (years)	Effect size (95% CI)	Variance	Standard error	Events/N	Weight (%)	Sensitivity analysis (overall effect size if study is left out)
Nyman & Lindhe, 1979	6.2	−3.84 (−4.59; −3.09)	0.15	0.38	7/332	28.95	−2.73
Laurell et al., 1991	8.4	−2.83 (−4.26; −1.41)	0.53	0.73	2/36	21.51	−3.13
Fardal & Linden, 2010	10.2	−3.83 (−5.23; −2.43)	0.51	0.71	2/94	21.78	−2.84
Yi et al., 1995	15.0	−1.82 (−2.68; −0.96)	0.19	0.44	6/43	27.76	−3.66
Overall (weighted)	9.7	−3.06 (−4.17; −1.95)	0.32	0.57	17/505		
Prediction interval (for 9.7 years)		4.60% (0%; 100%)					
I² 77.53; T² 0.96							
Years of follow-up							Predicted failure (%)
5							1.62
10							4.64
15							13.27
(c) Technical complications at restoration level							
	Follow-up (years)	Effect size (95% CI)	Variance	Standard error	Events/N	Weight (%)	Sensitivity analysis (overall effect size if study is left out)
Nyman & Lindhe, 1979	6.2	−2.47 (−2.87; −2.07)	0.04	0.20	26/332	76.15	−2.72
Laurell et al., 1991	8.4	−2.83 (−4.26; −1.41)	0.53	0.73	2/36	6.00	−2.51
Fardal & Linden, 2010	10.2	−2.69 (−3.51; −1.86)	0.18	0.42	6/94	17.85	−2.49
Overall (weighted)	7.2	−2.53 (−2.88; −2.18)	0.03	0.18	34/462		
Prediction Interval (for 7.2 years)		7.97% (0.82%; 77.0%)					

(Continues)

TABLE 4 (Continued)

(c) Technical complications at restoration level							Sensitivity analysis (overall effect size if study is left out)
	Follow-up (years)	Effect size (95% CI)	Variance	Standard error	Events/N	Weight (%)	
I^2 0.00; T^2 0.00							
Years of follow-up						Predicted complication (%)	
5						9.26	
10						6.86	
15						5.08	

Abbreviation: CI, confidence interval.

Data on PROMs and health economic parameters were either not or inconsistently reported. Yi, Carlsson, et al. (2001), in a dedicated publication, described a generally high degree of satisfaction. The five patients provided with restorative therapy reported similar levels of function, when compared to a dentate control group, but also more difficulty in carrying out oral hygiene procedures. No functional or aesthetic problems were noted in the cohort described by Li et al. (2017), but one out of 17 patients provided with full-arch restorations on four implants reported initial phonetic problems, which resolved within 1 month after prosthesis delivery. A cost analysis was presented by Barootchi et al. (2020), based on a retrospective assessment of initial cost and cost related to complications. Depending on the type of supraconstruction, the average annual cost per single implant during follow-up ranged from \$292 to \$485.

4 | DISCUSSION

In the present systematic review, the efficacy of fixed full-arch restorations supported by either teeth or implants in periodontally compromised patients (stage IV periodontitis) was evaluated. A total of 26 studies (31 publications) were identified, but none addressed the scientific question in a controlled and randomized design. The risk of bias throughout the included studies was judged to be high, and meta-analyses demonstrated a high degree of heterogeneity. The predicted loss of teeth and tooth-supported full-arch restorations over 10 years was 1% and 5%, respectively. The 15-year estimates were 10% and 13%, respectively. The corresponding predictions for implants and implant-supported restorations were possible for 10 years and amounted to 4% and 6%, respectively. Technical complications were the most commonly reported and affected 8% of tooth-supported restorations (during 7.2 years) and 42% of implant-supported structures (during 2.6 years). Biological complications at teeth were only inconsistently reported. Peri-implantitis or peri-implantitis-like symptoms were observed in an estimated 9% of implants (after 3.1 years).

No study could be identified that compared the two treatment strategies in a controlled and randomized manner. This may be explained by ethical considerations when designing studies on complex restorative therapy in periodontally compromised patients. Comparisons between outcomes of different treatment methods based solely on data from observational research may be compromised by unknown confounding factors (Grimes & Schulz, 2002). Nevertheless, while estimated proportions of implant and tooth loss, as well as loss of restorations, were similar for the two treatment methods, the review suggested a difference in the occurrence of technical complications. The estimated 5-year value of 46% calculated for implant restorations is in line with other reports. Thus, Karlsson et al. (2018), in a retrospective analysis of patient records, noted that a total of 25% of all patients were affected by at least one technical complication during an observation period of 5.3 years. The authors further observed that the hazard ratio was twice as high for full-jaw as for less extensive restorations. The observed differences between the occurrence of technical complications at tooth- and implant-supported restorations may be explained by the high rate of minor complications (e.g., chipping or veneering) related to patients' need to adapt to a new occlusal scheme under less discriminatory proprioception at implants (i.e., osseoperception) when compared to teeth (Klineberg & Murray, 1999; Klineberg et al., 2005; Piancino et al., 2017).

The present estimated rate of implant loss of 4% over 10 years is in line with other reports including wider patient groups and covering similar time frames (Derks et al., 2015; Jemt et al., 2015; Daudt Polido et al., 2018;). This is noteworthy, as all included patient cohorts in the present review were provided with extensive therapy and had a history of advanced periodontitis. Both parameters have been identified as risk factors for implant loss and peri-implantitis (Roccuzzo et al., 2010; Roccuzzo et al., 2012; Derks et al., 2015; Derks et al., 2016). The wide prediction interval observed for the outcome implant loss (0.4–34.3%) may be partly explained by the inclusion of studies with varying treatment approaches. The majority of relevant publications (15 out of 19), however, applied prosthetic loading within 24 h of implantation. It should also be noted, however, that 10-year

TABLE 5 Implant-supported full-arch fixed prostheses—loss/complication rates

(a) Loss of implants							
	Follow-up (years)	Effect size (95% CI)	Variance	Standard error	Events/ N	Weight (%)	Sensitivity analysis (overall effect size if study is left out)
Tealdo et al., 2008	1.0	−2.56 (−3.27; −1.84)	0.13	0.37	8/111	9.10	−3.46
Barbier et al., 2012	1.5	−5.48 (−8.26; −2.71)	2.01	1.42	0/120	3.44	−3.25
Grunder, 2001	1.6	−2.48 (−3.26; −1.71)	0.15	0.39	7/91	8.94	−3.46
Bechara et al., 2017	2.0	−4.67 (−6.06; −3.28)	0.50	0.71	2/215	6.87	−3.22
Adell et al., 1986	3.0	−5.25 (−8.03; −2.47)	2.01	1.42	0/95	3.43	−3.26
Alves et al., 2010	3.0	−4.42 (−5.81; −3.02)	0.51	0.71	2/168	6.86	−3.25
Yi, Carlsson, et al., 2001	3.0	−4.26 (−7.05; −1.47)	2.03	1.42	0/35	3.41	−3.31
Martens et al., 2014	4.7	−2.84 (−3.51; −2.17)	0.12	0.34	9/163	9.24	−3.43
Horwitz & Machtei, 2012	5.0	−0.92 (−1.65; −0.18)	0.14	0.37	10/35	9.06	−3.46
Li et al., 2017	5.0	−4.37 (−6.34; −2.40)	1.01	1.01	1/80	5.13	−3.28
Malo et al., 2007	5.0	−5.59 −7.55; −3.62)	1.00	1.00	1/268	5.16	−3.19
Malo et al., 2012	5.0	−2.93 (−4.09; −1.77)	0.35	0.59	3/59	7.64	−3.39
Tallarico et al., 2016	5.0	−3.32 (−4.07; −2.56)	0.15	0.38	7/200	9.00	−3.37
Tealdo et al., 2014	6.0	−2.16 (−2.82; −1.51)	0.11	0.33	10/97	9.29	−3.49
Windael et al., 2018	10.0	−4.80 (−7.58; −2.01)	2.02	1.42	0/60	3.43	−3.28
Overall (weighted)	3.9	−3.34 (−3.97; −2.71)	0.10	0.32	60/1797		
Prediction Interval (for 3.9 years)		3.54% (0.37%; 34.27%)					
I ² 77.99; T ² 1.00							
Years of follow-up							Predicted failure (%)
5							3.44
10							3.62
(b) Loss of restorations							
	Follow-up (years)	Effect size (95% CI)	Variance	Standard error	Events/ N	Weight (%)	Sensitivity analysis (overall effect size if study is left out)
Grunder et al., 2001	1.6	−3.04 (−5.88; −0.21)	2.10	1.45	0/10	9.41	−3.10
Riemann et al., 2019	2.0	−5.48 (−6.87; 4.09)	0.50	0.71	2/482	13.56	−2.46
Yi, Carlsson, et al., 2001	3.0	−2.56 (−5.44; 0.31)	2.15	1.47	0/6	9.31	−3.15
Barootchi et al., 2020	5.0	−1.29 (−1.84; −0.73)	0.08	0.28	16/74	15.35	−3.43
Malo et al., 2012	5.0	−0.59 (−1.68; 0.51)	0.31	0.56	5/14	14.31	−3.52
Tallarico et al., 2016	5.0	−4.39 (−7.18; −1.61)	2.02	1.42	0/40	9.54	−2.95
Tealdo et al., 2014	6.0	−4.60 (−7.38; −1.81)	2.02	1.42	0/49	9.55	−2.93
Shigehara et al., 2015	9.0	−4.04 (−6.84; −1.25)	2.04	1.43	0/28	9.52	−2.99
Windael et al., 2018	10.0	−3.14 (−5.97; −0.30)	2.09	1.44	0/11	9.43	−3.09
Overall (weighted)	3.2	−3.09 (−4.46; −1.72)	0.49	0.70	23/714		
Prediction Interval (for 3.2 years)		4.55% (0.40%; 100.00%)					
I ² 82.70; T ² 3.12							
Years of follow-up							Predicted failure (%)
5							4.55
10							5.84

(Continues)

TABLE 5 (Continued)

(c) Technical complications at restoration level							
	Follow up (years)	Effect size (95% CI)	Variance	Standard error	Events/ N	Weight (%)	Sensitivity analysis (overall effect size if study is left out)
Barbier et al., 2012	1.5	−3.71 (−6.52; −0.91)	2.05	1.43	0/20	2.86	−0.80
Grunder et al., 2001	1.6	−0.85 (−2.20; 0.51)	0.48	0.69	3/10	8.52	−0.91
Bechara et al., 2017	2.0	−2.83 (−4.26; −1.41)	0.53	0.73	2/36	7.98	−0.69
Riemann et al., 2019	2.0	−0.40 (−0.59; −0.22)	0.01	0.09	193/482	20.71	−1.04
Yi, Carlsson, et al., 2001	3.0	0.69 (−1.00; 2.39)	0.75	0.87	4/6	6.33	−1.00
Li et al., 2017	5.0	−1.10 (−2.11; −0.09)	0.27	0.52	5/20	11.57	−0.87
Malo et al., 2012	5.0	−0.29 (−1.35; 0.77)	0.29	0.54	6/14	11.10	−0.98
Tallarico et al., 2016	5.0	−1.39 (−2.16; −0.61)	0.16	0.40	8/40	14.26	−0.80
Tealdo et al., 2014	6.0	−0.54 (−1.12; 0.04)	0.09	0.30	18/49	16.67	−1.00
Overall (weighted)	2.6	−0.89 (−1.40; −0.38)	0.07	0.26	239/677		
Prediction Interval (for 2.6 years)		41.70% (9.42%; 100.00%)					
I ² 68.10; T ² 0.32							
Years of follow-up						Predicted complication (%)	
5						46.3	
10						76.3	
(d) Biological complications at implant level							
	Follow-up (years)	Effect size (95% CI)	Variance	Standard error	Events/N	Weight (%)	Sensitivity analysis (overall effect size if study is left out)
Barbier et al., 2012	1.5	−5.48 (−8.26; −2.71)	2.01	1.42	0/120	2.25	−2.39
Grunder et al., 2001	1.6	−2.65 (−3.48; −1.82)	0.18	0.42	6/91	9.46	−2.46
Bechara et al., 2017	2.0	−6.07 (−8.84; −3.29)	2.00	1.42	0/215	2.26	−2.37
Riemann et al., 2019	2.0	−2.26 (−2.41; −2.12)	0.01	0.08	196/2081	13.54	−2.62
Yi, Carlsson, et al., 2001	3.0	−1.39 (−2.21; 0.56)	0.18	0.42	7/35	9.45	−2.59
Cercadillo-Ibarguren et al., 2017	4.1	−1.79 (−2.08; −1.50)	0.02	0.15	54/378	13.02	−2.65
Martens et al., 2014	4.7	−2.73 (−3.37; −2.09)	0.11	0.33	10/163	10.81	−2.45
Barootchi et al., 2020	5.0	−1.32 (−1.55; −1.10)	0.01	0.12	95/452	13.29	−2.59
Li et al., 2017	5.0	−4.37 (−6.34; −2.40)	1.01	1.01	1/80	3.85	−2.39
Malo et al., 2007	5.0	−6.07 (−8.03; −4.11)	1.00	1.00	1/433	3.88	−2.29
Malo et al., 2012	5.0	−2.18 (−3.02; −1.33)	0.19	0.43	6/59	9.34	−2.51
Windael et al., 2018	10.0	−2.40 (−3.31; −1.48)	0.22	0.47	5/60	8.84	−2.49
Overall (weighted)	3.1	−2.47 (−2.93; −2.02)	0.05	0.23	381/4167		
Prediction Interval (for 3.1 years)		8.46% (1.92%; 37.25%)					
I ² 88.45; T ² 0.39							
Years of follow-up						Predicted complication (%)	
5						7.8	
10						9.5	

(Continues)

TABLE 5 (Continued)

(e) Biological complications at restoration level							
	Follow-up (years)	Effect size (95% CI)	Variance	Standard error	Events/N	Weight (%)	Sensitivity analysis (overall effect size if study is left out)
Bechara et al., 2017	2.0	−4.29 (−7.08; −1.50)	2.03	1.42	0/36	12.84	−1.83
Tallarico et al., 2016	5.0	−1.95 (−2.88; −1.01)	0.23	0.48	5/40	54.82	−2.64
Windael et al., 2018	10.0	−1.50 (−3.04; 0.03)	0.61	0.78	2/11	32.34	−2.74
Overall (weighted)	4.4	−2.10 (−3.18; −1.03)	0.30	0.55	7/87		
Prediction Interval (for 4.4 years)		12.25% (0.00%; 100.00%)					
I² 33.38; T² 0.32							
Years of follow-up							Predicted complication (%)
5							8.9
10							28.1

estimates in this case were based on observations limited to less than 5 years. Ideally, long-term studies should be the basis for solid evaluations of complication rates. The lack of robustness of the presented estimates is further underlined by the high levels of heterogeneity, as illustrated by the wide prediction intervals (IntHout et al., 2016; Borenstein et al., 2017). The reader should also be aware of a potential bias. In the present review, a significant small-study effect (Egger et al., 1997) was observed for the outcome implant loss.

The present review identified a number of additional limitations when addressing the efficacy of either tooth- or implant-supported fixed full-arch restorations in periodontally compromised patients. The inclusion criteria in terms of periodontal status/history to define study populations, namely patients with advanced periodontitis, varied considerably. For obvious reasons, the case definitions of the relevant studies did not consider the staging criteria suggested at the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions (Papapanou et al., 2018). In addition, particularly in studies on implant therapy, the periodontal history of edentulous patients or the reason for extraction of the remaining dentition was frequently unreported. This lack of information was the primary reason for the exclusion of studies from the present review. Because of the limited number of available studies, two publications (Martens et al., 2014; Barootchi et al., 2020) including periodontally compromised patients at a slightly lower level than initially required were included in the present analysis.

The analysis of the identified studies highlighted potential concerns in terms of external validity of the reported findings. This may be exemplified by the fact that the available studies on tooth-supported restorations originated from few clinical centres located in one geographical region. In addition, the majority of these studies included long follow-up periods (≥ 10 years) but were performed >30 years ago. An additional concern in this context is the relatively short observation periods covered by the more recent studies on implant-supported restorative therapy (≤ 5 years), which results in less precise estimates of 10-year projections in the present review.

The majority of studies on implants were described by the authors as prospective in nature. This suggests a higher level of data accuracy when compared to the purely retrospective studies on teeth (Euser et al., 2009). The fact that follow-up periods were frequently described through mean values and ranges, however, is in conflict with a truly prospective study design, by which all study subjects should be evaluated at given time points. Based on this general inconsistency, the present review did not analyse retrospective and prospective studies (as defined by the authors) separately. The reader should also be aware that risk for bias in patient selection and in outcome measurement was found to be serious in all studies. Interpretation of the assessment of publication bias was difficult, as it was mostly based on a limited number of studies. The evaluation of implant loss, on the other hand, included the largest number of studies, and results of the Egger test indicated an imbalance in effect size between studies with small and large standard errors.

Although biological complications at tooth-supported restorations could not be summarized, the rate of endodontic complications was reported to be 15% (at the tooth level) after 13 years in one study (Bergenholtz & Nyman, 1984). In the present review, the 10-year estimated rate of biological complications at implants was 10%. The reader should be aware, however, that case definitions of biological complications varied between studies. While some authors (Martens et al., 2014; Cercadillo-Ibarguren et al., 2017; Li et al., 2017) clearly defined peri-implantitis, others reported only on the occurrence of marginal bone loss (Yi, Ericsson, et al., 2001; Barbier et al., 2012). In addition, none of the studies reported on the actual need for interventions. The estimated rate of peri-implantitis or peri-implantitis-like symptoms, however, corresponded well with other reports on the prevalence of peri-implantitis at the implant level (Derks et al., 2016; Rodrigo et al., 2018; Wada et al., 2019).

An additional limitation presently highlighted is the lack of data on PROMs and on parameters related to health economics in regard to tooth- or implant-supported restorations evaluated in the present review. The occurrence of complications and the need for preventive dental care are likely to add substantial cost to the already extensive

resources to be invested at the time of fabrication. Thus, it is currently impossible to assess differences in the balance between cost and benefit between the two treatment alternatives. It is obvious that the studies on tooth-supported restorations included in the present review originated from a different time period when compared to the publications on implant-supported restorative therapy. Despite the fact that demands in terms of study design, data analysis, and reporting have evolved over time, data and conclusions from these older studies still remain valid. Nevertheless, the lack of more recent studies in this field highlights the need for well-designed, registered studies on the prosthetic rehabilitation of periodontally compromised individuals.

5 | CONCLUSIONS

Based on our review, we arrived at the following conclusions:

For patients with advanced periodontitis stage IV in need of full-arch rehabilitation

- no studies were identified that directly compared the efficacy of tooth- and implant-supported restorations;
- estimated tooth loss at 10 years was lower (1.1%) when compared to the corresponding estimate for implant loss (3.6%);
- estimated loss of tooth-supported restorations at 10 years (4.6%) was similar to the corresponding estimate for implant-supported restorations (5.8%);
- technical complications were more prevalent at implant-supported when compared to tooth-supported restorations;
- mean-weighted observation periods in studies on tooth-supported restorations (9.7/12.7 years) were significantly longer when compared to studies on implant-supported restorations (3.2/3.9 years). The potential impact of limited observation periods on precision of long-term projections should be considered.

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CONFLICT OF INTEREST

The authors declare no conflict of interest in regard to the present work.

AUTHOR CONTRIBUTIONS

Cristiano Tomasi, Jan Derks and Jean-Pierre Albouy contributed to study conception and design. All authors contributed to online and hand search. Two reviewers (Dennis Schaller and Renata Camino Navarro) independently extracted data. Cristiano Tomasi and Jan Derks contributed to statistical analysis and data interpretation. All authors contributed to the drafting of the manuscript and critically revising the same.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Cristiano Tomasi  <https://orcid.org/0000-0002-3610-6574>

Jan Derks  <https://orcid.org/0000-0002-1133-6074>

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