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SYSTEMATIC REVIEW

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Effectiveness of implant-supported fixed partial denture in patients with history of periodontitis: A systematic review and meta-analysis

Maria Clotilde Carra[1,2,3] | Hélène Rangé[1,2,4] | Pieter-Jan Swerts[5] | Krizia Tuand[6] | Katleen Vandamme[5] | Philippe Bouchard[1,2,4]

[1]Department of Periodontology, U.F.R. d'Odontologie-Garanciere, Université de Paris, Paris, France

[2]Department of Periodontology, Service d'Odontologie, AP-HP, Rothschild Hospital, Paris, France

[3]Inserm, Population-based Epidemiologic Cohorts Unit, UMS 011, Villejuif, France

[4]Université de Paris, UR 2496, Paris, France

[5]KU Leuven Department of Oral Health Sciences & UZ Leuven Restorative Dentistry, Campus Sint-Rafaël, Leuven, Belgium

[6]KU Leuven Libraries, 2Bergen Désiré Collen Learning Centre, Leuven, Belgium

Correspondence
Maria Clotilde Carra and Philippe Bouchard, U.F.R. d'Odontologie-Garanciere, Department of Periodontology, Service of Odontology, Rothschild Hospital, Université de Paris, AP-HP, 5 rue Santerre, 75012, Paris France.
Emails: mclotildecarra@gmail.com; philippe.bouchard.perio@gmail.com

Abstract

Aim: This systematic review investigates the effectiveness of implant-supported fixed partial denture (IS-FPD) in patients with history of periodontitis (HP) vs. patients with no history of periodontitis (NHP).

Methods: A literature search was performed on different databases on May 2020. Prospective and retrospective studies assessing survival (primary outcome), success and biological/mechanical complications of IS-FPDs in HP vs. NHP patients at ≥1 year after implant loading were evaluated. Meta-analyses were conducted by estimating hazard ratio (HR), risk ratio (RR) and standardized mean differences (SMD) with 95% confidence intervals (CI) using random effect models.

Results: Of the initially identified 4096 articles, 349 underwent a full-text evaluation. Finally, 17 were included. Pooled data analyses showed that overall implant survival was significantly higher in the NHP than the HP group (HR = 2.06; 95% CI = 1.37–3.09; I^2 = 0%). This difference was noted when follow-up ≥5 years. The risk of peri-implantitis was higher in HP than NHP patients (RR = 3.3; 95% CI = 1.31–8.3; I^2 = 0%), whereas the mean marginal bone level change over time was not different between the groups (SMD = −0.16 mm; 95% CI = −1.04–0.73; I^2 = 98%).

Conclusions: In partially edentulous patients receiving IS-FPDs, a history of periodontitis is associated with poorer survival rate and higher risk of peri-implantitis during a 5–10 years period after implant loading.

KEYWORDS
dental implants, fixed dental prosthesis, fixed partial denture, fixed partial prosthesis, implant-supported rehabilitation, peri-implantitis, periodontal disease, periodontitis, success, survival

1 | INTRODUCTION

Severe periodontitis is the 6th most prevalent non-communicable disease in the world, with an age-standardized prevalence of 9.8% in 2017 (Bernabe et al., 2020; Frencken et al., 2017; Kassebaum et al., 2014). Untreated severe periodontitis is one of the leading causes of tooth loss in adulthood (Ramseier et al., 2017), associated with an important disability weight, ranked 77th among the top 100 detailed causes of disability-adjusted life-years (Marcenes et al., 2013).

Since the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions (Caton et al., 2018), periodontitis is identified according to a multidimensional staging and

grading system, which aims to capture the severity of the disease, the complexity of the treatment needed and the likelihood of progression (Tonetti et al., 2018). Stage IV periodontitis is the most advanced stage characterized by a collection of clinical features associated with disease severity (Papapanou et al., 2018; Tonetti et al., 2018). A recent study demonstrated the prognostic value of this classification system, showing that Stage IV periodontitis patients have a higher risk of periodontal-related tooth losses over a 10–30 years follow-up period compared to Stage I periodontitis (Hazard Ratio: 3.73; 95% confidence interval: 1.27–10.93) (Ravidà et al., 2020). Moreover, the risk of tooth loss in periodontitis patients appeared to be independently predicted by age, patient's compliance to treatment and follow-up visits, smoking, and diabetes, as well as the severity of alveolar bone loss, probing pocket depth, tooth mobility and furcation involvement (Helal et al., 2019). Thus, patients diagnosed with Stage IV periodontitis are likely to seek for dental treatments and oral rehabilitations in order to replace missing teeth.

Implant-supported fixed partial denture (IS-FPD) is a widespread option for rehabilitation of partial edentulism. However, long-term effectiveness of IS-FPD can be blunt by several biological and mechanical complications that may occur after implant placement or implant loading. A high incidence of mucositis and peri-implantitis has been reported (Gurgel et al., 2017; Jepsen et al., 2015). Treatments of peri-implant diseases remain highly heterogeneous, poorly effective, and still under investigation (Heitz-Mayfield et al., 2018; Roccuzzo et al., 2018; Tomasi et al., 2019). Periodontitis appeared to be a risk factor for peri-implant diseases and poorer implant survival (Ferreira et al., 2018; Lin et al., 2020; Safii et al., 2010; Sgolastra et al., 2015; Wen et al., 2014). Consequently, one can hypothesize that IS-rehabilitations are at risk in patients with a history of periodontitis.

The present systematic review aimed to answer to the following focus question formulated according to the PICO format: what is the effectiveness (i.e. survival) and risks (i.e. biological and mechanical complications) of IS-FPD in patients with a history of periodontitis compared to patients with no history of periodontitis at ≥1 year from implant loading?

CLINICAL RELEVANCE

Scientific rationale for the study: Implant-supported fixed partial denture is a widespread option for rehabilitation of partial edentulism in patients with Stage IV periodontitis.

Principal findings: Patients with HP have a poorer IS-FPD survival and a greater risk of peri-implantitis. No differences are detected in marginal bone level changes over time compared to patients with NHP. No conclusion can be drawn on IS-FPD success rate.

Practical implications: Clinicians should be aware that IS-FPD effectiveness is less favourable in patients with a history of periodontitis than in patients with no history of periodontitis. The early identification and control of the periodontal risk factors must be part of patient evaluation in implant dentistry.

2 | METHODS

2.1 | Protocol and registration

The protocol of the present systematic review and meta-analysis was developed following the PRISMA statements checklist (Moher et al., 2009) and registered in Prospero on 10 April 2020 (CRD42020179376).

2.2 | Eligibility criteria

The research question was constructed using the PICOS format, as follows:

1. (P), Participants: Partially edentulous adult patients.
2. (I), Interventions: Placement of implant-supported fixed partial dentures (IS-FPDs) to replace missing teeth in patients with a history of periodontitis (HP). No restriction was applied for the definition, classification, extent and severity of periodontitis. All types of dental implant placement protocols (e.g. one- or two-stage surgery) with or without associated bone graft procedures were eligible. No restrictions were applied concerning implant brands and characteristics.
3. (C), Comparison: Placement of IS-FPD in patients with no history of periodontitis (NHP).
4. (O), Outcomes: Effectiveness of IS-FPD, evaluated on one or more of the following outcomes:
   (i) Primary outcome: Dental implant survival, defined as % of implants being present at the last follow-up examination.
   (ii) Secondary outcomes: IS-FPD success rate, marginal bone level (MBL) changes over time (expressed in mm or % and evaluated on standardized radiographs), biological complications (including mucositis and peri-implantitis), mechanical/prosthetic complications (e.g. crown fracture), and patient-reported outcome measures (PROMS) (e.g. IS-FPD satisfaction, comfort).

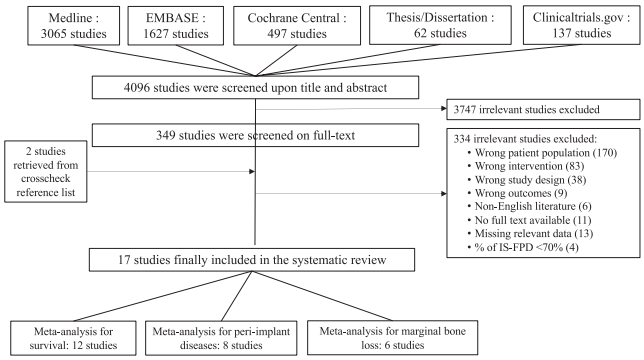


FIGURE 1 Flowchart of literature search and study selection

5. (S), Study design: All types of analytic studies with at least 1 year of follow-up (for every patient) from dental implant loading with the definitive FPD. The following study designs were considered: prospective and retrospective cohort studies, cross-sectional studies and case–control series (matched or not). No threshold was set for the minimum number of patients or implants included in the single studies.

Studies focusing on single-unit implant-supported crown or full-arch rehabilitation (fixed or removable) were not included in the systematic review. Mixed series, such as studies including cohort of patients receiving IS-FPD and other implant-supported restorations, were eligible for inclusion only if the proportion of IS-FPD was ≥70% (such as, single-units +full-arch rehabilitations <30%) over all implant-supported restorations considered in the study. Thus, to be selected, studies should display a ratio number of dental implants / number of patients >1 (for both HP and control groups), and a proportion of IS-FPD ≥70%.

2.3 | Information sources and search

The literature search strategy was defined by two teams of reviewers, one specialist in periodontology (MCC and HR) and the other in prosthodontics (KV and PJS), assisted by a research information specialist (KT). The following electronic databases were searched on May 2020 and updated on July 2020: MEDLINE (through PubMed), EMBASE, Cochrane Central Library, ProQuest Dissertations and Thesis, Open Access Thesis and Dissertation, openthesis.org, OpenGrey database and ClinicalTrials.gov. A unique and specific

TABLE 1 Characteristics of the selected studies including patients with IS-FPDs only

Reference Characteristics	Degidi et al., Clin Oral Impl Res 2016	Roccuzzo et al., Clin Oral Impl Res 2014	Jiang et al., Int J Oral Maxillofac Sur 2013
Study design Follow-up	Prospective cohort 10 years	Prospective cohort 10 years	Case–control 2 years
Setting, Country, Time frame	Private practice Italy 2001–2003	Private practice Italy 1998–2001	Unclear setting China NR
Total number of implants / patients	Baseline: 284/114 End of follow-up: 193/80	252/123	276/60
Number of implants/patients in the HP group (ratio)	81/32 (2.53)	198/91 (2.17) *Moderate periodontitis*: 96/46 (2.1) *Severe periodontitis*: 102/45 (2.3)	149/30 (4.9)
Number of implants/patients in the NHP group (ratio)	203/82 (2.47)	54/32 (1.7)	127/30 (4.2)
Definition of history of periodontitis	Any periodontal therapy prior to implant placement	Severe and moderate periodontitis based on the frequency and depth of periodontal pockets	Undetermined diagnosis of chronic periodontitis
Supportive periodontal / implant therapy	Every 6 months. Professional cleaning treatment by a dental hygienist	Individually tailored maintenance care programme	Unclear
Mean age, years (±SD, range)	Overall: 53.1 (±15.7)	HP group: *Moderate periodontitis*: 53.3 (±10.7) *Severe periodontitis*: 52.7 (±8.4) NHP group: 43.3 (±12.4)	HP group: 37 NHP group: 42
Female, n (%)	NR	NR	39 (65%)
Smokers, n (%)	34 (28.8%)	21 (17.1%)	NR
Significant imbalances between the HP and NHP groups	NR	Age, number of lost teeth	NR
Implants placement procedures	• Immediate loading • 32.7% of implants placed in post-extractive sites	• One stage implant placement • No bone augmentation / sinus lift	• Delayed implant placement • Delayed restoration approach
Implant brands	XiVE	Straumann (SLA)	NR
Funding source	Unknown	Unknown	Non-industry
Conflict of interest	Declared	NR	Declared

Abbreviations: HP: history of periodontitis; NHP: no history of periodontitis; NR: not reported; SLA: sandblasted and acid-etched.

search string was formulated for each database, using the following key concepts in different combinations: periodontitis, implant-supported fixed partial prosthesis and dental implant. For each key concept, database-specific index terms were combined with free text words (Table S1). In addition, reference lists from eligible studies and previously published review articles were cross-checked to identify additional pertinent studies. Only English literature was reviewed due to the time constraints.

2.4 | Study selection and data collection

Records from the literature searches on the different databases were merged into a single list imported in one EndNote library (EndNote™ software, Clarivate, US), in which duplicates were automatically removed. Four independent reviewers (MCC, HR, KV and PJS) proceeded to the study screening process by using Covidence software (https://www.covidence.org). Records were first screened at the title and abstract level. Each record had to be screened and voted (to be included or excluded) by two reviewers, blind of the other reviewers' assessment. Any disagreement was resolved by a third author (PhB), acting as tiebreaker. Subsequently, reviewers performed a full-text evaluation of the pre-selected articles. Similarly, this evaluation had to be performed in duplicate by two independent reviewers, and any disagreement was solved by the tiebreaker to reach the final selection of articles. Agreement between reviewers was assessed by estimating the % of agreement and the two-by-two kappa value.

A dedicated Microsoft Excel spreadsheet was created to facilitate the data extraction process, which was conducted by two

Roccuzzo et al., Clin Oral Impl Res 2010 and 2012	Serino et al., Clin Oral Impl Res 2009	Gatti et al., Eur J Oral Implantol 2008	Hardt et al., Clin Oral Impl Res 2002
Prospective cohort 10 years	Cross-sectional ≥5 years	Prospective cohort 5 years	Retrospective cohort 5 years
Private practice Italy 1996–1998	University/Hospital Sweden 2006	Private practice Italy 1990–2002	University/Hospital Sweden 1985–1991
Baseline: 246/112 End of follow-up: 228/101	109/23	227/62	346/97
185/73 (2.53) *Moderate periodontitis*: 95/36 (2.64) *Severe periodontitis*: 90/37 (2.43)	21/5 (4.2)	155/33 (4.7) *Moderate periodontitis*: 26/7 (3.7) *Severe periodontitis*: 129/26 (4.9)	100/25 (4)
61/28 (2.18)	88/18 (4.9)	72/29 (2.5)	92/25 (3.68)
Severe and moderate periodontitis based on the frequency and depth of periodontal pockets	At least one periodontal pocket ≥6 mm	Periodontal Screening and Recording (PSR) index	Age-related score of radiographic bone loss
Individually tailored maintenance care programme	NR	3- to 6-month recall programme	NR
HP group: *Moderate periodontitis*: 49 (±15.3) *Severe periodontitis*: 44 (±8.6) NHP group: 45 (±13)	Overall: 63.1 (range: 39–79)	HP group: *Moderate periodontitis*: 56 (35–85) *Severe periodontitis*: 56 (42–70) NHP group: 40 (18–61)	Overall: 57.6 (±14.6) HP group: 53.5 (±12.5) NHP group: 57.3 (±19.1)
NR	15 (65.2%)	39 (62.9%)	56 (57.7%)
18 (17.8%)	6 (26%)	14 (22.6%)	NR
No imbalance	NR	Age	NR
• One stage implant placement • No bone augmentation / sinus lift	NR	• 17.2% implants placed in augmented bone	• Conventional protocol • No bone augmentation
Straumann	ITI, Brånemark	Nobel Biocare, Zimmer Dental, Mathys, Straumann, Dentsply Friadent	Brånemark
Unknown	Unknown	Unknown	Unknown
NR	NR	NR	NR

TABLE 2 Characteristics of the selected studies including patients receiving different types of implant-supported prostheses, of which IS-FPDs represented ≥70%

Reference Characteristics	Graetz et al., Clin Oral Investig 2018	Roccuzzo et al. Clin Oral Implant Res 2017	Seki et al., Int J Implant Dent 2017	Wagenberg et al. Int J Oral Maxillofac Implants 2013
Study design Follow-up (range)	Matched case–control ≥5 years (5–23 years)	Prospective cohort 10 years	Cross-sectional 6.5 years	Retrospective cohort ≥ 1 year (1–22 years)
Setting Country Time frame	University/Hospital Germany 1982–1998	Private practice Italy 2000–2005	University/Hospital Japan 2016	University/Hospital USA 1988–2004
Total number of implants/patients	145/58	At baseline: 82/41 End of follow-up: 68/34	130/55	1187/541
Number of implants/patients in the HP group (ratio)	69/29 (2.37)	30/15 (2)	91/37 (2.45)	76/NR
Number of implants/patients in the NHP group (ratio)	76/29 (2.62)	38/18 (2.1)	39/18 (2.16)	1111/NR
Definition of history of periodontitis	Generalized chronic periodontitis based on 1999 AAP Classification	NR	Chronic periodontitis based on 1999 AAP Classification	Periodontal disease as reason for tooth extraction
Supportive periodontal / implant therapy	≥9 years with ≥1 visit/year followed by a 3- to 6-month recall programme for implant supportive therapy	Individually tailored maintenance care programme	3- to 6-month recall programme	NR
Mean age, years (±SD, range)	HP group: 56.0 (±10.8; range: 25–76) NHP group: 55.7 (±10.4; range: 28–71)	Overall: 48.5 (±10.6)	Overall: 63.53 (±10.51) HP group: 67.2 (±7.7) NHP group: 56.0 (±11.8)	Overall: 58.75 (±13.07) (12–88)
Female, n (%)	30 (51.7%)	28 (68.3%)	30 (54.5%)	NR
Smokers, n (%)	1 (1.7%)	NR	NR	NR
Significant imbalances between the patient groups	No imbalance (matched group)	NR	Age, number of missing teeth at implant placement, number of extracted teeth, maintenance period	NR
Implants placement procedures	NR	• Bone graft for vertical augmentation of at least 4 mm	• Two-stage surgery	• Post-extraction implant placement • 96.5% of two-stage surgery
Implant brands	NR	Straumann (SLA)	Replace Select™/ Steri-Oss® system, Novel Replace®, OsseoSpeed™, OSSEOTITE® XP, Brånemark system® Mk III	Nobel, 3i
Type of implant-supported restorations	• IS-FPD: 96.6% • Other: 3.4%	• IS-FPD: 73.5% • Single crowns: 26.5%	• IS-FPD: 70% • Single crowns: 30%	• IS-FPD: 81.8% • Single crowns: 18.2%
Funding source	Non-industry	Unknown	Non-industry	Unknown
Conflict of interest	Declared	NR	Declared	Declared

Abbreviations: AAP: American Academy of Periodontology; AgP: aggressive periodontitis; ChP: chronic periodontitis; HP: history of periodontitis; IS-FPD: implant-supported fixed partial denture; NHP: no history of periodontitis; NR: not reported.

Ormianer et al., Int J Oral Maxillofac Implants 2012	Rinke et al., Clin Oral Implant Res 2011	Simonis et al. Clin Oral Implants Res 2010	Wagenberg et al. Int J Oral Maxillofac Implants 2006	Mengel et al., J Periodontol 2005
Retrospective cohort ≥9.5 years	Retrospective cohort ≥2 years (2–11.3 years)	Retrospective cohort ≥10 years (10–16 years)	Retrospective cohort ≥1 year (1–16 years)	Prospective cohort 3 years
Private practice Israel NR	Private practice Germany 1999–2006	University/Hospital France 1990–1997	University/Hospital USA 1988–2004	University/Hospital Germany NR
173/46	288/71	At baseline: 162/76 At 10 years: 131/55	1925/891	147/39
138/30 (4.6)	228/51 (4.47)	34/NR	122/NR	*Overall:* 117/27 (4.3) *ChP*: 43/12 (3.6) *AgP*: 77/15 (5.1)
35/16 (2.2)	60/20 (3)	97/NR	1803/NR	30/12 (2.5)
NR	'Active' periodontal therapy (i.e. scaling and root planing or surgical therapy) within 5 years before implant placement	Periodontal disease as reason for tooth extraction	Periodontal disease as reason for tooth extraction	1999 AAP Classification
Recalls ≥1 / year	3- to 6-month recall programme	NR	NR	3-month recall programme
Overall: 51	Overall: 52.4 (±10.2) HP group: 54.2 (±9.6) NHP group: 47.7 (±10.3)	Overall: 68.7 (±12) (29–88)	Overall: 57.9 (14–94)	Overall: range 19–59 HP group: CP: 34 AgP: 32 NHP group: 31
27 (58.7%)	41 (57.7%)	34 (61.8%)	510 (57.2%)	21 (53.8%)
NR	13 (18.3%)	9 (16.4%)	NR	0
NR	NR	NR	NR	NR
• One- or two-stage surgery • Delayed or immediate loading • Bone graft when necessary	NR	NR	• Post-extraction implant placement • 3.3% immediate loading • 8.3% associated sinus lift	• Two-stage implant placement
NR	Ankylos	Straumann	Nobel, 3i	MKII (Nobel), Osseotite (3i)
• IS-FPD: 90.8% • Single crowns: 9.2%	• IS-FPD: 93.7% • Single crowns: 6.2%	• IS-FPD: 72.6% • Single crowns: 27.4%	• IS-FPD: 79.3% • Single crowns: 20.7%	• IS-FPD: 79.3% • Single crowns: 20.7%
Unknown	Unknown	Non-industry	Unknown	Unknown
NR	NR	NR	Declared	NR

reviewers independently (MCC and HR). Study characteristics and main findings were collected, analysed and then summarized in tables to be processed for qualitative and quantitative analyses. Where the same authors' team or single institution had published multiple reports with accumulating patient cohorts, the largest or most informative study was included in the quantitative analyses, according to the outcome of interest.

2.5 | Risk of bias assessment

Once completed the full-text article analysis, two reviewers (MCC and HR) completed the risk of bias evaluation, which was assessed by using appropriate tools according to the study design. Publication bias and sponsoring bias were also evaluated. The source of funding was classified as industry, industry-associated, non-industry or unknown (Popelut et al., 2010).

2.6 | Data synthesis and analysis

Whenever potentially relevant data were missing in the published document, an attempt was made to contact the corresponding author. The feasibility and appropriateness of meta-analyses were checked once completed data extraction and regrouped the selected studies by type of outcome. Outcome measures were extracted as mean (standard deviation, SD), median (interquartile range), frequency or rate (%), as provided. In the meta-analysis, the risk ratio (RR) and 95% confidence intervals (CI) were estimated using the Mantel–Haenszel method for binary outcomes. For continuous data, the standardized mean differences (SMD) with 95%CI between HP and NHP groups were estimated using inverse variance weighting. To compare survival rates between patient groups, hazard ratio (HR) and 95%CI were calculated as described by Tierney et al. (Tierney et al., 2007). Heterogeneity was assessed by the I^2 statistic, and values of 25%, 50% and 75% considered as low, moderate and high heterogeneity, respectively. Random effect models were used to adopt a more conservative approach, as a significant inter-study heterogeneity was expected. The robustness of the results and the potential sources of heterogeneity were explored by performing sensitivity analyses whenever indicated. The pooled effect was considered significant if $p < 0.05$. The meta-analysis was performed with RevMan software (Version 5.3; Cochrane Collaboration).

3 | RESULTS

3.1 | Study selection

The merged literature search allowed to initially identify 4096 original articles that underwent the screening process (Figure 1). Upon title and abstract, 3747 studies were judged as irrelevant and were excluded. The remaining 349 articles underwent a full-text evaluation; for 12 studies, we did not have access to the full text; we contacted the corresponding authors (via email or ResearchGate), but we were not able to obtain the documents, except for one study (Wagenberg & Froum, 2006). Two further studies were identified from the reference lists of the screened articles.

During full-text analysis, if critical information, such as the % of IS-FPD over the total number of implants/IS-restorations placed or the detailed outcomes measure in the HP and NHP groups were missing, corresponding authors were contacted in order to gather the missing data or to clarify the unclear issues. Only twelve authors of the 25 contacted (48%) responded to our emails and provided the missing information. Finally, 334 articles were excluded because not relevant to the review question or not meeting all inclusion criteria (Appendix S1). Thus, 17 articles were included in the present systematic review (Figure 1).

During the study selection process, the Cohen's kappa between the examiners was moderate to low, but with a proportionate agreement that ranged between 84% and 100% (Appendix S2).

3.2 | Study characteristics

The selected studies included 7 prospective and 10 retrospective studies. Six were conducted in Italy (35.3%), 3 in Germany, 2 in Sweden, 2 in the United States, 1 in Israel, 1 in China, 1 in Japan and 1 in France.

Eight studies (47%) investigated the effectiveness of IS-FPD in cohorts of partially edentulous patients receiving IS-FPD only (no other types of prosthesis) (Degidi et al., 2016; Gatti et al., 2008; Hardt et al., 2002; Jiang et al., 2013; Roccuzzo et al., ,2010, 2012, 2014; Serino & Strom, 2009). Among them, two articles reported different outcomes from the same study population (Roccuzzo et al., ,2010, 2012) and were thus considered as one study. Overall, these 8 studies considered 889 implants placed in 289 HP patients versus 697 implants placed in 244 NHP patients (control group) (Table 1).

The remaining 9 studies (Graetz et al., 2018; Mengel & Flores-de-Jacoby, 2005; Ormianer & Patel, 2012; Rinke et al., 2011; Seki et al., 2017; Simonis et al., 2010; Wagenberg & Froum, 2006; Wagenberg et al., 2013) included patients receiving different types of IS-restorations, of which IS-FPD corresponded to ≥70% (range 70%–96.6%). Two studies were conducted by the same investigators on the same study population but with different follow-up durations (Wagenberg & Froum, 2006; Wagenberg et al., 2013). Three studies did not specify the number of patients per group, since they used the implant as statistical unit (Simonis et al., 2010; Wagenberg & Froum, 2006; Wagenberg et al., 2013); these latter 3 studies contributed with 156 implants placed in HP patients and 1900 implants placed in NHP patients. In the other 6 studies, overall, 673 implants were placed in 189 HP patients versus 278 implants in 113 NHP patients (Table 2).

The definition of HP varied among the studies. Four studies differentiated between moderate and severe forms of periodontitis (Gatti et al., 2008; Roccuzzo et al., ,2010, 2012, 2014) but used different criteria. One study differentiated between aggressive and chronic

periodontitis according to the AAP Classification of 1999 (Mengel & Flores-de-Jacoby, 2005). Two studies identified patients with a HP based on previous periodontal treatments (Degidi et al., 2016; Rinke et al., 2011), whereas 3 studies defined periodontal disease as the reason for tooth extraction (Simonis et al., 2010; Wagenberg & Froum, 2006; Wagenberg et al., 2013). In 4 studies, implants were placed in post-extractional sites with or without immediate loading (Degidi et al., 2016; Ormianer & Patel, 2012; Wagenberg & Froum, 2006; Wagenberg et al., 2013), in 4 studies bone graft procedures were eventually associated (Gatti et al., 2008; Ormianer & Patel, 2012; Roccuzzo et al., 2017; Wagenberg & Froum, 2006), and in 9 studies conventional one- or two-stage protocols were followed (Hardt et al., 2002; Jiang et al., 2013; Mengel & Flores-de-Jacoby, 2005; Ormianer & Patel, 2012; Roccuzzo et al., 2012, 2014; Seki et al., 2017; Wagenberg & Froum, 2006; Wagenberg et al., 2013), with great heterogeneity within the single studies (Tables 1 and 2).

The type of supportive periodontal therapy and supportive dental implant therapy was reported in 11/17 studies (Degidi et al., 2016; Gatti et al., 2008; Graetz et al., 2018; Mengel & Flores-de-Jacoby, 2005; Ormianer & Patel, 2012; Rinke et al., 2011; Roccuzzo et al., 2010, 2012, 2014, 2017; Seki et al., 2017). Regarding the outcomes, implant survival was reported in 14 studies (Degidi et al., 2016; Gatti et al., 2008; Graetz et al., 2018; Hardt et al., 2002; Jiang et al., 2013; Mengel & Flores-de-Jacoby, 2005; Ormianer & Patel, 2012; Roccuzzo et al., 2010, 2012, 2014, 2017; Simonis et al., 2010; Wagenberg & Froum, 2006), implant/prosthesis success in 3 studies (Degidi et al., 2016; Gatti et al., 2008; Ormianer & Patel, 2012), peri-implant disease rate in 10 studies (Degidi et al., 2016; Gatti et al., 2008; Rinke et al., 2011; Roccuzzo et al., 2010, 2012, 2014, 2017; Seki et al., 2017; Serino & Strom, 2009; Simonis et al., 2010), radiographic MBL changes over time in 12 studies (Degidi et al., 2016; Gatti et al., 2008; Graetz et al., 2018; Hardt et al., 2002; Mengel & Flores-de-Jacoby, 2005; Ormianer & Patel, 2012; Roccuzzo et al., 2010, 2012, 2014, 2017; Simonis et al., 2010; Wagenberg et al., 2013) and prosthetic complications in 2 studies (Degidi et al., 2016; Ormianer & Patel, 2012). Definitions for peri-implant diseases and methods used to assess radiographic MBL varied among the selected studies (Table S2). Only one study considered PROMs evaluated upon questionnaire, but the outcome was reported for the overall study population and not by groups (comparison between HP vs. NHP patients was not reported) (Simonis et al., 2010).

3.3 | Synthesis of the results

The outcomes of the selected studies are summarized in Table 3.

3.3.1 | Survival rate

Pooled data analyses showed that implant survival was significantly higher in the NHP group than HP group, with an overall HR of 2.06 of surviving for implants placed in NHP patients. Interestingly, no group difference was noted in studies with a follow-up shorter than 5 years (Figure 2).

Sensitivity analyses were conducted to investigate the impact of periodontitis severity and the homogeneity of the patient cohorts under investigation. Based on 3 studies (Gatti et al., 2008; Roccuzzo et al., 2012, 2014), corresponding to 321 implants placed in patients with severe periodontitis versus 217 implants placed in patients with moderate periodontitis, no significant difference was noted for implant survival over a 5 to 10 years follow-up period (HR: 1.31; 95% CI: 0.58–2.96; $p = 0.52$; $I^2 = 0\%$). Hence, this subset of patients with history of severe periodontitis showed an increased risk of implant loss compared to NHP patients, that, however, did not reach a statistical significance (RR: 3.12; 95% CI: 0.92–10.57; $p = 0.99$; $I^2 = 0\%$).

Concerning the type of study design, similar findings were noted when considering prospective and retrospective studies separately. Based on the 6 prospective cohort studies only (Degidi et al., 2016; Gatti et al., 2008; Mengel & Flores-de-Jacoby, 2005; Roccuzzo et al., 2012, 2014, 2017), accounting for 740 implants placed in HP patient vs. 458 implants placed in NHP patients, a significant higher implant survival was found for implants placed in NHP patients (HR: 2.42; 95% CI: 1.19–4.94; $p = 0.01$; $I^2 = 0\%$). Based on the 6 retrospective studies (Graetz et al., 2018; Hardt et al., 2002; Jiang et al., 2013; Ormianer & Patel, 2012; Simonis et al., 2010; Wagenberg & Froum, 2006) accounting for 612 implants placed in HP patients vs. 2230 implants placed in NHP patients, a significant higher implant survival was found in favour of this latter group (HR: 1.91; 95% CI: 1.16–3.12; $p = 0.01$; $I^2 = 0\%$).

While analysing the failure rates of IS-FPD in studies considering patients receiving IS-FPD only (Degidi et al., 2016; Gatti et al., 2008; Hardt et al., 2002; Jiang et al., 2013; Roccuzzo et al., 2012, 2014), implants placed in the HP group had a significantly greater RR to fail over time (RR: 2.12; 95% CI: 1.10–4.07; $p = 0.02$; $I^2 = 0\%$) compared to implants placed in the NHP group. Similar results were found when analysing the 6 studies on mixed cohorts in which IS-FPD corresponded to ≥70% (Graetz et al., 2018; Mengel & Flores-de-Jacoby, 2005; Ormianer & Patel, 2012; Roccuzzo et al., 2017; Simonis et al., 2010; Wagenberg & Froum, 2006), with a greater risk of failure for implants placed in HP patients (RR: 1.81; 95% CI: 1.15–2.84; $p = 0.01$; $I^2 = 0\%$) (Figure S1).

Reasons for implant failure were specified in 11/14 studies (78.6%). The most frequent complication leading to implant loss was peri-implantitis (Degidi et al., 2016; Gatti et al., 2008; Hardt et al., 2002; Roccuzzo et al., 2010, 2012, 2014, 2017; Simonis et al., 2010; Wagenberg & Froum, 2006). Other reasons included implant fracture or trauma (Simonis et al., 2010; Wagenberg & Froum, 2006), lack/loss of osseointegration (Degidi et al., 2016; Simonis et al., 2010; Wagenberg & Froum, 2006), implant mobility (Jiang et al., 2013; Mengel & Flores-de-Jacoby, 2005), and pain or paresthesia (Simonis et al., 2010; Wagenberg & Froum, 2006). No study reported differences between the HP and NHP groups concerning the reasons of implant failure.

TABLE 3 Summary of the outcomes reported of the selected studies

Outcomes Reference	Survival rate	Peri-implant diseases rate	Radiographic marginal bone level changes
Studies including patients with IS-FPDs only			
Degidi et al., Clin Oral Impl Res 2016	Overall: 96.4% HP group: 96.3% NHP group: 97.5%	*Mucositis*: Overall: 35 (18.13%) implants in 26 (32.5%) patients *Peri-implantitis*: Overall: 16 (8.29%) implants in 14 (17.5%) patients	HP group: at 12 months: 0.89 mm (±0.17); 24 months: 1.07 mm (±0.18); 5 years; 1.48 mm (±0.27); 10 years: 2.01 mm (±0.27) NHP group: at 12 months: 0.83 mm (±0.21); 24 months: 1.02 mm (±0.22); 5 years; 1.40 mm (±0.29); 10 years: 2.79 mm (±0.34)
Roccuzzo et al., Clin Oral Impl Res 2014	HP group: *Moderate periodontitis*: 96.9% *Severe periodontitis*: 97.1% NHP group: 100%	*Peri-implantitis:* HP group: *Moderate periodontitis*: 52.2% of patients *Severe periodontitis*: 66.7% of patients NHP group: 18.8% of patients	HP group: *Moderate periodontitis*: 9.4% of implants *Severe periodontitis*: 10.8% of implants with a bone loss ≥3 mm NHP group: 0%
Jiang et al., Int J Oral Maxillofac Sur 2013	HP group: 95.9% NHP group: 97.6%	NR	NR
Roccuzzo et al., Clin Oral Impl Res 2010 and Clin Oral Impl Res 2012	HP group: *Moderate periodontitis*: 92.8% *Severe periodontitis*: 90% NHP group: 96.6%	*Peri-implantitis*: HP group: *Moderate periodontitis*: 27% of patients *Severe periodontitis*: 47.2% of patients NHP group: 10.7% of patients	HP group: *Moderate periodontitis*: 1.14 (±1.11) mm *Severe periodontitis*: 0.98 (±1.22) NHP group: 0.75 (±0.88) mm
Serino et al., Clin Oral Impl Res 2009	NR	*Peri-implantitis*: HP group: 11/21 implants (52%) NHP group: 47/88 implants (53%)	NR
Gatti et al., Eur J Oral Implantol 2008	HP group: *Moderate periodontitis*: 100% *Severe periodontitis*: 98.4% NHP group: 100%	*Peri-implantitis*: HP group: *Moderate periodontitis*: no implant *Severe periodontitis*: 4/129 (3.1%) implants NHP group: no implant	HP group: *Moderate periodontitis*: 2.80 (±0.45) mm *Severe periodontitis*: 2.63 (±1.06) NHP group: 1.37 (±1.04) mm
Hardt et al., Clin Oral Impl Res 2002	HP group: 92% NHP group: 96.7%	NR	HP group: 16 (64%) patients and 62% of implants with a mean bone loss >2 mm NHP group: 6 (24%) patients and 44% of implants
Studies including different types of implant-supported prostheses, of which IS-FPDs represented ≥70%			
Graetz et al., Clin Oral Investig 2018	HP group: at 5 years: 97.1% at 10 years: 92.5% NHP group: at 5 years: 97.4% at 10 years: 91.4%	NR	NR
Roccuzzo et al. Clin Oral Implant Res 2017	HP group: 90% NHP group: 97.4%	*Peri-implant disease*: HP group: 12/30 implants (40%) NHP group: 7/38 implants (18.4%)	HP group: 0.78 (±0.59) mm NHP group: 0.43 (±0.5) mm
Seki et al., Int J Implant Dent 2017	NR	*Peri-implantitis*: HP group: 14/91 implants (15.4%) corresponding to 3/37 patients (16.2%) NHP group: 0%	NR

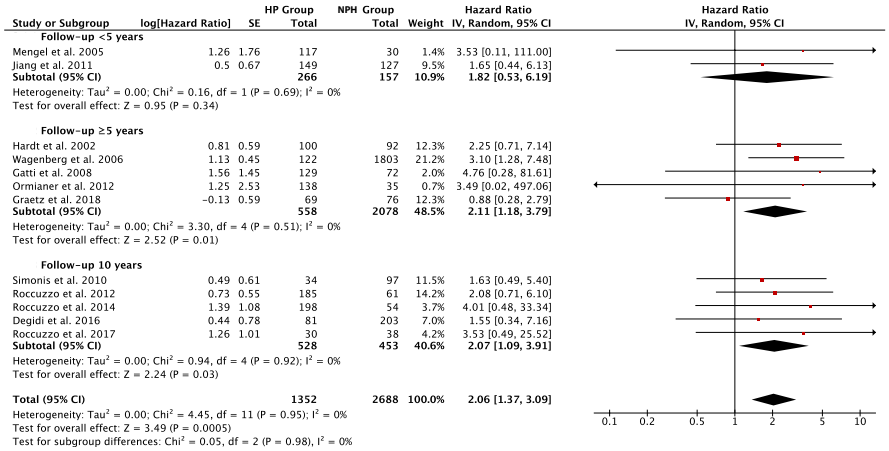
(Continues)

TABLE 3 (Continued)

Outcomes Reference	Survival rate	Peri-implant diseases rate	Radiographic marginal bone level changes
Wagenberg et al. Int J Oral Maxillofac Implants 2013	NR	NR	HP group: 0.43 (±0.68) mm NHP group: 0.54 (± 0.83) mm
Ormianer et al., Int J Oral Maxillofac Implants 2012	HP group: 99.3% NHP group: 100%	NR	HP group: 85 (62%) implants without bone loss; 18 (13.1%) implants with 1.5 mm of bone loss; 3 implants >2.5 mm bone loss, and 1 implant >3.5 mm NHP group: 30 (85.7%) implants without bone loss; 3 (8.6%) implants with 1.5 mm of bone loss, and no implant with >2.5 mm of bone loss
Rinke et al., Clin Oral Implant Res 2011	NR	*Mucositis*: HP group: 30 (58.8%) patients NHP group: 5 (25%) patients *Peri-implantitis*: HP group: 7 (13.7%) patients NHP group: 1 (5%) patient	NR
Simonis et al. Clin Oral Implants Res 2010	HP group: 85.3% NHP group: 90.6%	*Peri-implantitis:* HP group: 37.9% of patients NHP group: 10.5% of patients	Overall: 2.2 ± 3.4 mm
Wagenberg et al. Int J Oral Maxillofac Implants 2006	HP group: 91.8% NHP group: 96.3%	NR	NR
Mengel et al., J Periodontol 2005	HP group: 98.3% NHP group: 100%	NR	HP group: ChP at 1 year: 0.68 (±0.54) mm; at 3 year: 0.18 (±0.11) mm AgP: at 1 year: 0.83 (± 0.71) mm; at 3 year: 0.31 (±0.22) mm NHP group: at 1 year: 0.58 (±0.45) mm; at 3 year: 0.12 (±0.08) mm

Abbreviations: HP: history of periodontitis; NHP: no history of periodontitis; NR: not reported.

FIGURE 2 Forest plot for implant survival



Three studies also reported the rate of tooth loss during the follow-up for HP and NHP patients receiving IS-FPDs (Graetz et al., 2018; Roccuzzo et al., 2010, 2014). One study found that the mean tooth loss during the 10-year observation period was not significantly different between groups, although NHP patients had a lower incidence of tooth loss (4.2%) compared to HP patients with moderate (6.5%) or severe periodontitis (7%) (Roccuzzo et al., 2010). Conversely, another study reported that the mean number of teeth lost during the supportive periodontal therapy was 0.7 ± 1.0 for NHP patients, 1.3 ± 1.3 for moderate periodontitis and 1.9 ± 1.9 for severe periodontitis, with a significant difference among the three groups, particularly evident for patients non-compliant to periodontal follow-up (Roccuzzo et al., 2014). Similarly, Graetz et al. reported a 20% rate of tooth loss for HP patients during an observation period

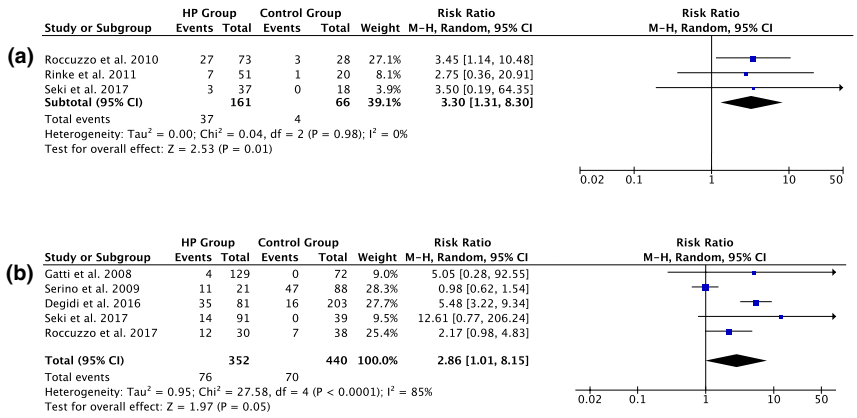


FIGURE 3 Forest plot for peri-implantitis rate. (a) Rate at the patient level. (b) Rate at the implant level

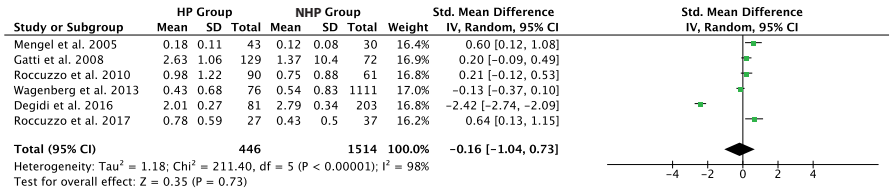


FIGURE 4 Forest plot for marginal bone level changes over time (mm) at the implant level

of 11.0±5.6 years, whereas only 6.4% of teeth present at baseline were extracted in NHP patients (Graetz et al., 2018).

3.3.2 | Success rate

Due to the heterogeneity in reporting, no pooled data analysis was possible for this outcome. Success rate was evaluated by Degidi et al., 2016 (Degidi et al., 2016) over a 10-year prospective follow-up, and it was estimated at 62.6% for the overall study population. In the prospective cohort study by Gatti et al. (Gatti et al., 2008) over a 5-year follow-up, 1/48 prosthesis failed in the severe periodontitis group due to advanced peri-implantitis (success rate: 97.9%), whereas no failure was observed in the groups of patients with moderate periodontitis or periodontally healthy (success rate: 100%). In the retrospective cohort study by Ormianer et al. over a follow-up of ≥9.5 years, the overall success rate was 90.9% (Ormianer & Patel, 2012).

Prosthetic complications were reported in details by Degidi et al., 2016 (Degidi et al., 2016) but only for the overall study population (n = 80 patients, 193 implants). They concerned the 39.5% of patients and included repeated relining procedure (2.6%), small fractures or chipping (7.9%), loosening of the temporary abutment screw (3.5%), dissatisfaction with the colour shade (0.9%), loosening of the final abutment screw (0.9%), detachment of the prosthesis because of cement failure (7.9%), minor chipping of the porcelain veneer of the final restoration (7.9%) and complete detachment of the ceramic veneer (6.1%). Ormianer et al. (Ormianer & Patel, 2012) reported cement failure (n = 1), porcelain fracture (n = 11), framework fracture (n = 1) in the HP group and cement failure (n = 1), porcelain fracture (n = 1) and framework fracture (n = 1) in the NHP group, without significant differences between the groups.

3.3.3 | Peri-implantitis rate.

The risk of peri-implantitis was evaluated at the patient and implant level. Patients with a HP had a RR of 3.3 of developing peri-implantitis over the follow-up period compared to NHP patients. This was also observed at the implant level, although with a greater heterogeneity (I^2: 85%) (Figure 3).

3.3.4 | MBL changes

Four studies (Graetz et al., 2018; Hardt et al., 2002; Ormianer & Patel, 2012; Roccuzzo et al., 2014) reported MBL changes as % of the implant height and were not used for the pooled data analysis. Thus, based on the remaining 6 studies (Degidi et al., 2016; Gatti et al., 2008; Mengel & Flores-de-Jacoby, 2005; Roccuzzo et al., 2010, 2017; Wagenberg et al., 2013), in which the MBL change over time was estimated on radiographs and expressed in mm, there was no difference in MBL between implants placed in HP and NHP patients (Figure 4).

3.4 | Risk of bias

According to the type of study design, the Newcastle-Ottawa Scale (NOS) (Stang, 2010) for cohort and case–control studies was used to assess the risk of bias. Overall, 10 studies (58.8%) were considered at low risk of bias (≥7/9 stars) (Table S3). Funding sources were unknown in the majority of studies (12/17; 70.6%), and a conflict of interest declaration was present only in 6 studies (35.3%) (Tables 1 and 2).

A funnel plot was built only for the primary outcome, that is implant survival, because it was the only outcome assessed on at least 10 studies (Higgins & Green, 2011). It showed an asymmetric plot with the majority of the studies clustered at the top and towards the right of the graph. This display suggested the presence of publication bias (Figure S2).

4 | DISCUSSION

4.1 | Main findings

The present systematic review, based on a relevant number of studies, patients and implants, demonstrates that IS-FPDs placed in HP patients have a poorer long-term survival and a greater risk of peri-implantitis compared to IS-FPDs placed in NHP patients. No differences between the HP and NHP groups are detected for MBL changes over time, and no conclusion can be drawn on IS-FPD overall success rate, this outcome being poorly investigated and reported. In addition, the paucity of data on the occurrence of mechanical/prosthetic complications and about PROMS also prevent to conclude on these outcomes.

Dental implants represent a valuable and widespread therapeutic option to replace missing teeth. Although associated with high and predictable long-term success and survival rates in general (Fu & Wang, 2020), patients receiving IS-rehabilitations need to be informed about the potential risks and complications that may occur over time. First, the occurrence of peri-implant diseases is rather large with a weighted mean prevalence (at the patient level) across Europe and South and North America of peri-implant mucositis and peri-implantitis estimated at 43% and 22%, respectively (Derks & Tomasi, 2015). Second, the prevalence of peri-implantitis increases over time, as it is observed after a 5–10 years follow-up (Derks & Tomasi, 2015; Fu & Wang, 2020), and it appears to be the most frequent cause of implant loss. Thus, all efforts should be made to prevent peri-implant inflammation and infection by controlling potential risk factors prior to implant placement (Heitz-Mayfield et al., 2018).

A history of periodontitis has been reported as positively associated with poorer survival rates and peri-implantitis in general (Ferreira et al., 2018; Fu & Wang, 2020; Lin et al., 2020; Wen et al., 2014). The present meta-analysis demonstrates that IS-FPDs, concerning at least 2 implants, placed in patients with HP have a worse prognosis than IS-FPDs placed in NHP patients. This is highly relevant in treatment plans that require complex rehabilitations to replace multiple missing teeth. With an overall survival rate of 95.1% vs. 97.9%, HP patients have approximately 2 times the risk of losing their implants compared to NHP patients over time. A survival rate of 95% at 10 years after loading may be considered as adequate or acceptable, but, however, it does not consider the occurrence of complications that can drastically impact on the treatment success despite the fact that the implant may still in place. Indeed, also the risk of biological complications, namely peri-implantitis, is 3.3 times higher in HP patients than NHP patients. This factor should drive clinicians to carefully evaluate the risks/benefits ratio in the choice of the prosthetic rehabilitation and to adopt individualized protocols for periodontal and implant follow-up. Alternatives to IS-FPDs include tooth-supported FPDs and removable prostheses. Although they are suitable treatments even in patients with a history of periodontitis, using periodontally compromised teeth as abutments may be risky and increase the rate of tooth loss (Bäumer et al., 2020; Pretzl et al., 2008). Moreover, HP patients are more susceptible to continue to lose teeth over time compared to NHP patients, especially when they are diagnosed with stage IV periodontitis or if they are not compliant to periodontal follow-ups (Graetz et al., 2018; Ravidà et al., 2020; Roccuzzo et al., 2012, 2014).

Multiple factors can explain the increased susceptibility to peri-implant diseases and consequently to poorer implant survival in HP patients. These include genetic components determining host responses, specific compositions and abundance of pathogens in the oral microbiota, systemic comorbidities, lifestyle habits (e.g. smoking), and erratic or non-compliant behaviours towards oral hygiene and periodontal follow-ups (Fu & Wang, 2020). Most of these factors can be managed prior to implant placement and monitored during all different steps of IS-rehabilitation, from the early postoperative period to the individualized implant supportive care phase. However, risk factor control is highly difficult to achieve in daily practice, involving multidimensional aspects for both dentists and patients, and it is hardly captured in research studies in which the numerous confounding factors mentioned above are rarely considered in the statistical analyses. Moreover, there is an important 'time effect', as revealed by the present study based on a considerable number of publications with mid and long-term follow-ups. Indeed, even if the breakdown of peri-implant diseases is sudden, the long-term clinical follow-up of dental implants is the cornerstone of their evaluation. Follow-ups shorter than 5 years appear to be insufficient to detect a significant difference in implant survival between HP and NHP patients. To our knowledge, the present study not only updates what was previously reported but it definitely strengthens the evidence of the role of periodontitis on peri-implant diseases occurrence in patients requiring IS-FPDs.

4.2 | Methodological considerations

The present review was conducted by following a systematic approach involving multiple reviewers expert in periodontology and prosthodontics in order to provide the most exhaustive evaluation of the currently available studies on the effectiveness of IS-FPD in patients with HP. Quantitative pooled data analyses were possible for a consistent number of studies and the majority of the considered outcomes; moreover, sensitivity analyses were performed to assess the robustness of the results taking into account, whenever possible, the type of IS-rehabilitation, the study design and the severity of the disease.

However, the present systematic review highlighted some limitations of the current literature. All studies were based on convenience samples of patients, mostly of limited size. No experimental study was found (e.g. RCT), and only 7/17 studies (41/2%) provided a prospective patient's follow-up. There was a variety of case definitions for both exposure (i.e. history of periodontitis) and outcomes (i.e. peri-implantitis), which suggests a generalized lack of consensus in research. This is expected to improve in the near future following the implementation of recently developed disease classification and treatment guidelines (Berglundh et al., 2018; Caton et al., 2018; Papapanou et al., 2018; Sanz et al., 2020). However, this should be considered as a potential drawback of the current evidence. Moreover, it must be noted that in the field of implant dentistry the proposed case definitions should be viewed within the context that there is no generic or standardized implant, but numerous implant designs with different surface characteristics, surgical and loading protocols, which characterize a heterogeneous clinical practice (mirrored in the high pooled data heterogeneity observed for some implant-related outcomes, such as MBL).

Unfortunately, there is a lack of relevant data about the success rate of IS-FPDs in HP and NHP patients. Implant success rate is defined as the dental implant and the prosthetic reconstruction being present in the mouth of the patient as functional and without any type of complication (biological and mechanical) (Albrektsson et al., 1986), which should also include the aesthetic outcomes and patient's satisfaction (PROMS). The detection of an unsuccessful implant may occur long time before implant failure (i.e. implant loss) and may require multiple treatments to manage it. Thus, this outcome should be assessed on a yearly basis to capture short-term complications that may precede implant loss and to better describe the clinical risks related to IS-FPD in HP vs. NHP patients.

Based on the current literature, it was not possible to specifically identify patients with Stage IV periodontitis, being all the included studies based on previous classification systems. A high heterogeneity was observed in the definitions used in the single studies, being most of the time impossible to correctly assess the severity of periodontitis or the susceptibility to disease progression (corresponding to periodontitis grade), although in all studies the disease was successfully managed before implant placement. It could be advocated that patients with a history of Stage IV periodontitis may more likely need IS-FPDs due to the multiple periodontitis-related tooth loss (Ravidà et al., 2020). This may also lead to subsequent alveolar bone resorption that represents a clinical challenge to achieve functional restorations. Ridge resorption may imply regenerative procedures for vertical and/or horizontal bone augmentation that can also have an impact on implant success and survival rates (Elnayef et al., 2017; Sanz-Sánchez et al., 2015). Furthermore, bite collapse and occlusal discrepancy may increase the complexity of the oral rehabilitation requiring multidisciplinary treatments (Tonetti et al., 2018). These aspects, however, could not be precisely ascertained from the current literature, and caution is required in the interpretation and generalization of the present results to the specific patient population today identified as suffering from stage IV periodontitis.

Despite that pooled data analyses tend to minimize the effects of potential confounders by considering larger samples, it must be acknowledged that it was not possible to distinguish the role of the multiple factors potentially impacting on IS-FPD outcomes. For example, 8/17 studies (47%) considered both non-smokers and smokers, the latter group representing 1.7%-28.8% of the patient sample. One study considered non-smokers only (Mengel & Flores-de-Jacoby, 2005), whereas the remaining 7 studies did not provide any detail about smoking habits. Similarly, multiple implant brands, implant placement protocols (e.g. one-stage, two-stage surgery and bone augmentation), implant site location (e.g. mandibular, maxillary) and IS-restorations (e.g. materials, number of units) were included. If this may capture a more realistic picture of the clinical daily practice, it definitely introduces bias and confounders potentially influencing the association between the exposure and the outcome. Finally, publication and sponsoring bias may have an impact in the field of implant dentistry. Efforts were made to minimize the risk of publication bias by performing an exhaustive literature search including theses, dissertations, grey literature and unpublished researches. However, the funnel plot generated for studies dealing with implant survival suggests the presence of publication bias that needs to be considered in the critical appraisal of the literature. Moreover, 47% of the selected studies were conducted in private practice settings, and 70% did not report the source of funding, making impossible to estimate the role of sponsoring bias.

5 | IMPLICATIONS FOR FUTURE RESEARCH

Future research studies may consider the following issues:

- To improve study design by including larger sample size and longer prospective follow-up (>5 years), with outcome assessment at multiple time points in order to identify the long-term evolution of risk and those factors that may impact on it (e.g. patient's compliance to implant supportive care protocols).
- To consider experimental trials to assess effectiveness and risk of IS-FPD in highly controlled settings (e.g. implant design, type of implant placement protocol).
- To adopt standardized case definitions for periodontitis and implant outcomes, including survival, success and peri-implant diseases occurrence.
- To evaluate specific clinical outcomes, such as probing depth, bleeding on probing, suppuration and radiographic bone loss around implants (and teeth) with standardized measures and reporting.
- To systematically report mechanical/prosthetic complications and success rate in patients treated with IS-FPDs.

- To investigate the role of comorbidities and lifestyle habits, significantly associated with periodontitis, on the long-term effectiveness of IS-FPDs.
- To evaluate PROMS.

6 | IMPLICATIONS FOR CLINICAL PRACTICE

- Clinicians should be aware that IS-FPD effectiveness may be less favourable in patients with a history of periodontitis than patients with no history of periodontitis.
- Efforts should be made to promote risk factor control prior to implant placement, particularly in patients with a history of periodontitis.
- Efforts should be made to insure a personalized periodontal follow-up for these patients, which will allow clinicians to promptly detect the first signs of inflammation around implants and prevent the occurrence of peri-implantitis and ultimately IS-FPD failure.

7 | CONCLUSIONS

In partially edentulous patients receiving IS-FPDs, a history of periodontitis is associated with a poorer survival rate and an increased risk of peri-implantitis over a 5–10 years follow-up period after implant loading.

CONFLICT OF INTEREST

The authors have no conflict of interest to disclose.

ORCID

Maria Clotilde Carra https://orcid.org/0000-0002-5717-3274
Hélène Rangé https://orcid.org/0000-0002-4761-0805
Pieter-Jan Swerts https://orcid.org/0000-0002-9431-7759
Krizia Tuand https://orcid.org/0000-0003-2670-5415
Katleen Vandamme https://orcid.org/0000-0002-5766-2254
Philippe Bouchard https://orcid.org/0000-0002-9905-3967

REFERENCES

Albrektsson, T., Zarb, G., Worthington, P., & Eriksson, A. R. (1986). The long-term efficacy of currently used dental implants: a review and proposed criteria of success. *International Journal of Oral and Maxillofacial Implants*, *1*, 11–25.

Bäumer, A., Weber, D., Staufer, S., Pretzl, B., Körner, G., & Wang, Y. (2020). Tooth loss in aggressive periodontitis: Results 25 years after active periodontal therapy in a private practice. *Journal of Clinical Periodontology*, *47*, 223–232. https://doi.org/10.1111/jcpe.13225

Berglundh, T., Armitage, G., Araujo, M. G., Avila-Ortiz, G., Blanco, J., Camargo, P. M., Chen, S., Cochran, D., Derks, J., Figuero, E., Hämmerle, C. H. F., Heitz-Mayfield, L. J. A., Huynh-Ba, G., Iacono, V., Koo, K.-T., Lambert, F., McCauley, L., Quirynen, M., Renvert, S., … Zitzmann, N. (2018). Peri-implant diseases and conditions: Consensus report of workgroup 4 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. *Journal of Clinical Periodontology*, *45*(Suppl 20), S286–s291. https://doi.org/10.1111/jcpe.12957

Bernabe, E., Marcenes, W., Hernandez, C. R., Bailey, J., Abreu, L. G., Alipour, V., Amini, S., Arabloo, J., Arefi, Z., Arora, A., Ayanore, M. A., Bärnighausen, T. W., Bijani, A., Cho, D. Y., Chu, D. T., Crowe, C. S., Demoz, G. T., Demsie, D. G., Dibaji Forooshani, Z. S., … Kassebaum, N. J. (2020). Global, regional, and national levels and trends in burden of oral conditions from 1990 to 2017: A systematic analysis for the global burden of disease 2017 study. *Journal of Dental Research*, *99*, 362–373. https://doi.org/10.1177/0022034520908533

Caton, J. G., Armitage, G., Berglundh, T., Chapple, I. L. C., Jepsen, S., Kornman, K. S., Mealey, B. L., Papapanou, P. N., Sanz, M., & Tonetti, M. S. (2018). A new classification scheme for periodontal and peri-implant diseases and conditions - Introduction and key changes from the 1999 classification. *Journal of Clinical Periodontology*, *45*(Suppl 20), S1–s8. https://doi.org/10.1111/jcpe.12935

Degidi, M., Nardi, D., & Piattelli, A. (2016). 10-year prospective cohort follow-up of immediately restored XiVE implants. *Clinical Oral Implants Research*, *27*, 694–700. https://doi.org/10.1111/clr.12642.

Derks, J., & Tomasi, C. (2015). Peri-implant health and disease. A systematic review of current epidemiology. *Journal of Clinical Periodontology*, *42*(Suppl 16), S158–171. https://doi.org/10.1111/jcpe.12334

Elnayef, B., Monje, A., Gargallo-Albiol, J., Galindo-Moreno, P., Wang, H. L., & Hernández-Alfaro, F. (2017). Vertical ridge augmentation in the atrophic mandible: A systematic review and meta-analysis. *International Journal of Oral and Maxillofacial Implants*, *32*, 291–312. https://doi.org/10.11607/jomi.4861

Ferreira, S. D., Martins, C. C., Amaral, S. A., Vieira, T. R., Albuquerque, B. N., Cota, L. O. M., Esteves Lima, R. P., & Costa, F. O. (2018). Periodontitis as a risk factor for peri-implantitis: Systematic review and meta-analysis of observational studies. *Journal of Dentistry*, *79*, 1–10. https://doi.org/10.1016/j.jdent.2018.09.010

Frencken, J. E., Sharma, P., Stenhouse, L., Green, D., Laverty, D., & Dietrich, T. (2017). Global epidemiology of dental caries and severe periodontitis - a comprehensive review. *Journal of Clinical Periodontology*, *44*(Suppl 18), S94–s105. https://doi.org/10.1111/jcpe.12677

Fu, J. H., & Wang, H. L. (2020). Breaking the wave of peri-implantitis. *Periodontology 2000*, *84*(1), 145–160. https://doi.org/10.1111/prd.12335.

Gatti, C., Gatti, F., Chiapasco, M., & Esposito, M. (2008). Outcome of dental implants in partially edentulous patients with and without a history of periodontitis: A 5-year interim analysis of a cohort study. *European Journal of Oral Implantology*, *1*, 45–51.

Graetz, C., El-Sayed, K. F., Geiken, A., Plaumann, A., Sälzer, S., Behrens, E., Wiltfang, J., & Dörfer, C. E. (2018). Effect of periodontitis history on implant success: A long-term evaluation during supportive periodontal therapy in a university setting. *Clinical Oral Investigations*, *22*, 235–244. https://doi.org/10.1007/s00784-017-2104-4

Gurgel, B. C. V., Montenegro, S. C. L., Dantas, P. M. C., Pascoal, A. L. B., Lima, K. C., & Calderon, P. D. S. (2017). Frequency of peri-implant diseases and associated factors. *Clinical Oral Implants Research*, *28*, 1211–1217. https://doi.org/10.1111/clr.12944

Hardt, C. R., Grondahl, K., Lekholm, U., & Wennstrom, J. L. (2002). Outcome of implant therapy in relation to experienced loss of periodontal bone support: A retrospective 5- year study. *Clinical Oral Implants Research*, *13*, 488–494. https://doi.org/10.1034/j.1600-0501.2002.130507.x

Heitz-Mayfield, L. J., Aaboe, M., Araujo, M., Carrión, J. B., Cavalcanti, R., Cionca, N., Cochran, D., Darby, I., Funakoshi, E., Gierthmuehlen, P. C., Hashim, D., Jahangiri, L., Kwon, Y., Lambert, F., Layton, D. M., Lorenzana, E. R., McKenna, G., Mombelli, A., Müller, F., … Yeo, A. (2018). Group 4 ITI Consensus Report: Risks and biologic complications associated with implant dentistry. *Clinical Oral Implants Research*, *29*(Suppl 16), 351–358. https://doi.org/10.1111/clr.13307

Helal, O., Göstemeyer, G., Krois, J., Fawzy El Sayed, K., Graetz, C., & Schwendicke, F. (2019). Predictors for tooth loss in periodontitis patients: Systematic review and meta-analysis. *Journal of Clinical Periodontology*, *46*, 699–712. https://doi.org/10.1111/jcpe.13118

Higgins, J. P., & Green, S. (2011). *Cochrane handbook for systematic reviews of interventions* (Version 5.1.0 [updated March 2011] ed.): The Cochrane Collaboration.

Jepsen, S., Berglundh, T., Genco, R., Aass, A. M., Demirel, K., Derks, J., Figuero, E., Giovannoli, J. L., Goldstein, M., Lambert, F., Ortiz-Vigon, A., Polyzois, I., Salvi, G. E., Schwarz, F., Serino, G., Tomasi, C., & Zitzmann, N. U. (2015). Primary prevention of peri-implantitis: Managing peri-implant mucositis. *Journal of Clinical Periodontology*, *42*(Suppl 16), S152–157. https://doi.org/10.1111/jcpe.12369

Jiang, B. Q., Lan, J., Huang, H. Y., Liang, J., Ma, X. N., Huo, L. D., & Xu, X. (2013). A clinical study on the effectiveness of implant supported dental restoration in patients with chronic periodontal diseases. *International Journal of Oral and Maxillofacial Surgery*, *42*, 256–259. https://doi.org/10.1016/j.ijom.2012.08.001

Kassebaum, N. J., Bernabé, E., Dahiya, M., Bhandari, B., Murray, C. J., & Marcenes, W. (2014). Global burden of severe periodontitis in 1990–2010: A systematic review and meta-regression. *Journal of Dental Research*, *93*, 1045–1053. https://doi.org/10.1177/0022034514552491

Lin, C. Y., Chen, Z., Pan, W. L., & Wang, H. L. (2020). Is history of periodontal disease still a negative risk indicator for peri-implant health under supportive post-implant treatment coverage? A systematic review and meta-analysis. *International Journal of Oral and Maxillofacial Implants*, *35*, 52–62. https://doi.org/10.11607/jomi.7714

Marcenes, W., Kassebaum, N. J., Bernabé, E., Flaxman, A., Naghavi, M., Lopez, A., & Murray, C. J. (2013). Global burden of oral conditions in 1990–2010: A systematic analysis. *Journal of Dental Research*, *92*, 592–597. https://doi.org/10.1177/0022034513490168

Mengel, R., & Flores-de-Jacoby, L. (2005). Implants in patients treated for generalized aggressive and chronic periodontitis: A 3-year prospective longitudinal study. *Journal of Periodontology*, *76*, 534–543. https://doi.org/10.1902/jop.2005.76.4.534

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G. & Group, P. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med*, *6*, e1000097. https://doi.org/10.1371/journal.pmed.1000097

Ormianer, Z., & Patel, A. (2012). The use of tapered implants in the maxillae of periodontally susceptible patients: 10-year outcomes. *International Journal of Oral and Maxillofacial Implants*, *27*, 442–448.

Papapanou, P. N., Sanz, M., Buduneli, N., Dietrich, T., Feres, M., Fine, D. H., Flemmig, T. F., Garcia, R., Giannobile, W. V., Graziani, F., Greenwell, H., Herrera, D., Kao, R. T., Kebschull, M., Kinane, D. F., Kirkwood, K. L., Kocher, T., Kornman, K. S., Kumar, P. S., … Tonetti, M. S. (2018). Periodontitis: Consensus report of workgroup 2 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. *Journal of Periodontology*, *89*(Suppl 1), S173–s182. https://doi.org/10.1002/jper.17-0721

Popelut, A., Valet, F., Fromentin, O., Thomas, A., & Bouchard, P. (2010). Relationship between sponsorship and failure rate of dental implants: A systematic approach. *PLoS One*, *5*, e10274. https://doi.org/10.1371/journal.pone.0010274

Pretzl, B., Kaltschmitt, J., Kim, T. S., Reitmeir, P., & Eickholz, P. (2008). Tooth loss after active periodontal therapy. 2: Tooth-related factors. *Journal of Clinical Periodontology*, *35*, 175–182. https://doi.org/10.1111/j.1600-051X.2007.01182.x

Ramseier, C. A., Anerud, A., Dulac, M., Lulic, M., Cullinan, M. P., Seymour, G. J., Faddy, M. J., Bürgin, W., Schätzle, M., & Lang, N. P. (2017). Natural history of periodontitis: Disease progression and tooth loss over 40 years. *Journal of Clinical Periodontology*, *44*, 1182–1191. https://doi.org/10.1111/jcpe.12782

Ravidà, A., Qazi, M., Troiano, G., Saleh, M. H. A., Greenwell, H., Kornman, K., & Wang, H.-L. (2020). Using periodontal staging and grading system as a prognostic factor for future tooth loss: A long-term retrospective study. *Journal of Periodontology*, *91*, 454–461. https://doi.org/10.1002/jper.19-0390

Rinke, S., Ohl, S., Ziebolz, D., Lange, K., & Eickholz, P. (2011). Prevalence of periimplant disease in partially edentulous patients: A practice-based cross-sectional study. *Clinical Oral Implants Research*, *22*, 826–833. https://doi.org/10.1111/j.1600-0501.2010.02061.x

Roccuzzo, M., Bonino, F., Aglietta, M., & Dalmasso, P. (2012). Ten-year results of a three arms prospective cohort study on implants in periodontally compromised patients. Part 2: Clinical results. *Clinical Oral Implants Research*, *23*, 389–395. https://doi.org/10.1111/j.1600-0501.2011.02309.x

Roccuzzo, M., Bonino, L., Dalmasso, P., & Aglietta, M. (2014). Long-term results of a three arms prospective cohort study on implants in periodontally compromised patients: 10-year data around sandblasted and acid-etched (SLA) surface. *Clinical Oral Implants Research*, *25*, 1105–1112. https://doi.org/10.1111/clr.12227

Roccuzzo, M., De Angelis, N., Bonino, L., & Aglietta, M. (2010). Ten-year results of a three-arm prospective cohort study on implants in periodontally compromised patients. Part 1: implant loss and radiographic bone loss. *Clinical Oral Implants Research*, *21*, 490–496. https://doi.org/10.1111/j.1600-0501.2009.01886.x

Roccuzzo, M., Layton, D. M., Roccuzzo, A., & Heitz-Mayfield, L. J. (2018). Clinical outcomes of peri-implantitis treatment and supportive care: A systematic review. *Clinical Oral Implants Research*, *29*(Suppl 16), 331–350. https://doi.org/10.1111/clr.13287

Roccuzzo, M., Savoini, M., Dalmasso, P., & Ramieri, G. (2017). Long-term outcomes of implants placed after vertical alveolar ridge augmentation in partially edentulous patients: A 10-year prospective clinical study. *Clinical Oral Implants Research*, *28*, 1204–1210. https://doi.org/10.1111/clr.12941

Safii, S. H., Palmer, R. M., & Wilson, R. F. (2010). Risk of implant failure and marginal bone loss in subjects with a history of periodontitis: A systematic review and meta-analysis. *Clinical Implant Dentistry and Related Research*, *12*, 165–174. https://doi.org/10.1111/j.1708-8208.2009.00162.x

Sanz, M., Herrera, D., Kebschull, M., Chapple, I., Jepsen, S., Berglundh, T., Sculean, A., Tonetti, M. S., Merete Aass, A., Aimetti, M., Kuru, B. E., Belibasakis, G., Blanco, J., Bol-van den Hil, E., Bostanci, N., Bozic, D., Bouchard, P., Buduneli, N., Cairo, F., … Wennström, J. (2020). Treatment of stage I-III periodontitis-The EFP S3 level clinical practice guideline. *Journal of Clinical Periodontology*, *47*(Suppl 22), 4–60. https://doi.org/10.1111/jcpe.13290

Sanz-Sánchez, I., Ortiz-Vigón, A., Sanz-Martín, I., Figuero, E., & Sanz, M. (2015). Effectiveness of lateral bone augmentation on the alveolar crest dimension: A systematic review and meta-analysis. *Journal of Dental Research*, *94*, 128s–142s. https://doi.org/10.1177/0022034515594780

Seki, K., Nakabayashi, S., Tanabe, N., Kamimoto, A., & Hagiwara, Y. (2017). Correlations between clinical parameters in implant maintenance patients: Analysis among healthy and history-of-periodontitis groups. *International Journal of Implant Dentistry*, *3*, 45. https://doi.org/10.1186/s40729-017-0108-0

Serino, G., & Strom, C. (2009). Peri-implantitis in partially edentulous patients: Association with inadequate plaque control. *Clinical Oral Implants Research*, *20*, 169–174. https://doi.org/10.1111/j.1600-0501.2008.01627.x

Sgolastra, F., Petrucci, A., Severino, M., Gatto, R., & Monaco, A. (2015). Periodontitis, implant loss and peri-implantitis. A meta-analysis. *Clinical Oral Implants Research*, *26*, e8–e16. https://doi.org/10.1111/clr.12319

Simonis, P., Dufour, T., & Tenenbaum, H. (2010). Long-term implant survival and success: A 10–16-year follow-up of non-submerged dental

implants. *Clinical Oral Implants Research*, *21*, 772–777. https://doi.org/10.1111/j.1600-0501.2010.01912.x

Stang, A. (2010). Critical evaluation of the Newcastle-Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses. *European Journal of Epidemiology*, *25*, 603–605. https://doi.org/10.1007/s10654-010-9491-z

Tierney, J. F., Stewart, L. A., Ghersi, D., Burdett, S., & Sydes, M. R. (2007). Practical methods for incorporating summary time-to-event data into meta-analysis. *Trials*, *8*, 16. https://doi.org/10.1186/1745-6215-8-16

Tomasi, C., Regidor, E., Ortiz-Vigón, A., & Derks, J. (2019). Efficacy of reconstructive surgical therapy at peri-implantitis-related bone defects. A systematic review and meta-analysis. *Journal of Clinical Periodontology*, *46*, 340–356. https://doi.org/10.1111/jcpe.13070

Tonetti, M. S., Greenwell, H., & Kornman, K. S. (2018). Staging and grading of periodontitis: Framework and proposal of a new classification and case definition. *Journal of Clinical Periodontology*, *45*(Suppl 20), S149–s161. https://doi.org/10.1111/jcpe.12945

Wagenberg, B., & Froum, S. J. (2006). A retrospective study of 1925 consecutively placed immediate implants from 1988 to 2004. *International Journal of Oral and Maxillofacial Implants*, *21*, 71–80.

Wagenberg, B. D., Froum, S. J., & Eckert, S. E. (2013). Long-term bone stability assessment around 1,187 immediately placed implants with 1- to 22-year follow-up. *International Journal of Oral and Maxillofacial Implants*, *28*, 605–612. https://doi.org/10.11607/jomi.2809

Wen, X., Liu, R., Li, G., Deng, M., Liu, L., Zeng, X. T., & Nie, X. (2014). History of periodontitis as a risk factor for long-term survival of dental implants: A meta-analysis. *International Journal of Oral and Maxillofacial Implants*, *29*, 1271–1280. https://doi.org/10.11607/jomi.3544

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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