Impact of rehabilitation versus edentulism on systemic health and quality of life in patients affected by periodontitis: A systematic review and meta-analysis

Gennai, Stefano; Izzetti, Rossana; Pioli, Maria C.; Music, Larisa; Graziani, Filippo

Received: 4 February 2021 | Revised: 27 May 2021 | Accepted: 21 June 2021

DOI: 10.1111/jcpe.13526

SYSTEMATIC REVIEW

Journal of Clinical Periodontology WILEY

Impact of rehabilitation versus edentulism on systemic health and quality of life in patients affected by periodontitis: A systematic review and meta-analysis

Stefano Gennai[1,2] | Rossana Izzetti[1,2] | Maria C. Pioli[1] | Larisa Music[3] | Filippo Graziani[1,2]

[1]Department of Surgical, Medical and Molecular Pathology and Critical Care Medicine, University of Pisa, Pisa, Italy

[2]Sub-Unit of Periodontology, Halitosis and Periodontal Medicine, University Hospital of Pisa, Pisa, Italy

[3]Department of Periodontology, School of Dental Medicine, University of Zagreb, Zagreb, Croatia

Correspondence
Filippo Graziani, Department of Surgical, Medical, Molecular and Critical Area Pathology, Unit of Dentistry and Oral Surgery, University Hospital of Pisa, Via Savi 10, 56126 Pisa, Italy.
Email: filippo.graziani@med.unipi.it

Funding information
Chair of Periodontology of the University of Pisa

Abstract

Aim: To investigate the effect of rehabilitation in fully/partially edentulous patients with stage IV periodontitis on oral-health-related quality of life (OHRQoL) and systemic health.

Materials and methods: A systematic electronic and manual search was conducted. Three authors independently reviewed, selected, and extracted the data. Outcomes were OHRQoL (Oral Health Impact Profile 14 [OHIP-14] and OHIP-49, General Oral Health Assessment Index [GOHAI], visual analogue scale, symptoms registration) and systemic health-related outcomes (incidence and prevalence of systemic diseases, values of systemic disease indicators). Qualitative data were synthesized for OHRQoL and systemic health-related outcomes. Meta-analysis was conducted on available quantitative data.

Results: The search identified 59 articles (6724 subjects in total). OHRQoL improved across all the studies, irrespective of the number of missing teeth, their location, or treatment modality. Meta-analysis showed significant improvement of OHIP-49 (36.86, $p < .01$) in manuscripts including subjects affected by periodontitis, consistently with the remaining literature (reduction of score points post rehabilitation: OHIP-14 = 10.52, OHIP-49 = 56.02, GOHAI = 5.40, $p < .01$ for all). Non-rehabilitated subjects exhibited inferior cognitive status, higher medication intake, and frailty. However, our data are limited and should be interpreted with caution.

Conclusions: Oral rehabilitation improves OHRQoL and, potentially, systemic health in edentulous patients. It is unclear whether these findings may be extrapolated to patients with stage IV periodontitis.

KEYWORDS
edentulism, periodontitis stage IV, quality of life, systemic health

Clinical Relevance

Scientific rationale for study: Edentulous subjects and subjects affected by periodontitis show inferior oral-health-related quality of life (OHRQoL) and systemic health issues. It is important to assess the impact of oral rehabilitation on such outcomes.

Principal findings: Oral rehabilitation does provide significant improvements in OHRQOL in subjects with or without periodontitis. There is a tendency for improvement of cognitive function and overall well-being.

Practical implications: Clinicians should be aware of the important impact of oral rehabilitation on primary patient-based outcomes.

1 | INTRODUCTION

Stage IV periodontitis is defined by disease severity on the basis of periodontal variables equal to stage III, but with tooth loss of a minimum of five elements and a need for complex rehabilitation (Papapanou et al., 2018). This condition often requires complex rehabilitation because of the presence of masticatory dysfunction (Papapanou et al., 2018). As a matter of fact, tooth loss is recognized as a major cause of functional impairment of oral functions. The unbalance arising following tooth extraction is related to the anatomical modifications of both hard and soft tissues following tooth loss (Araujo & Lindhe, 2005; Chappuis et al., 2013; Araújo et al., 2015; Graziani et al., 2019) and the subsequent difficulty in the masticatory function. Among the consequences related to tooth loss, dietary restrictions, difficulties with speech, loss of support for facial musculature, and a reduction in vertical facial height represent some of the conditions compromising normal oral physiology (Harris et al., 2013). Moreover, edentulism, whether partial or total, appears to be associated with unfavourable aesthetics and psychological outcomes in patients (Craddock, 2009). Finally, tooth loss significantly diminishes the quality of life (QoL) of patients (Gerritsen et al., 2010).

Both dentures and bridges are frequently employed as therapeutic options for the management of partial or total edentulism (Moldovan et al., 2018). Rehabilitation of edentulism can be evaluated in terms of both functional and patient-related outcome measures. The functional efficiency of prosthetic restorations, masticatory ability, continued use of a prosthesis, and absence of technical or biological complications are reliable parameters to evaluate the success of prosthodontic treatment (Gunne, 1985; Kern & Wagner, 2001; Sailer et al., 2007; Papaspyridakos et al., 2012). On the other hand, the impact of any rehabilitation also needs to be viewed in the context of its impact on patients' lives. These patient-reported outcome measures capture the evaluation of the impact of dental treatment on health status and QoL (Yao et al., 2018), and usually employ a multidimensional construct, through psychometric testing, assessing the impact of oral problems on functional, aesthetic, and psychosocial well-being (McGrath & Bedi, 2001; Slade & Spencer, 1994). Interestingly, oral rehabilitation has been reported to be associated with a significant improvement in oral-health-related quality of life (OHRQoL) (John et al., 2004; Ali et al., 2019).

It is reasonable to propose that oral rehabilitation following tooth loss may not be confined to local improvement but may be extended to systemic health. In particular, it has been reported that correct masticatory function can have an impact on cognitive function and nutritional status (Kossioni, 2018).

Thus, the present systematic review aimed to evaluate the impact of oral rehabilitation in partially or completely edentulous patients affected by periodontitis stage IV in terms of OHRQoL and systemic health-related outcomes.

2 | MATERIALS AND METHODS

2.1 | Protocol development and eligibility criteria

A detailed protocol was prepared according to the Preferred Reporting Items Systematic review and Meta-Analyses Extension Statement for Reporting of Systematic Reviews Incorporating Network Meta-analyses of Health Care Interventions (Liberati et al., 2009; Moher et al., 2009; Hutton et al., 2015).

The review protocol was registered in the PROSPERO International (Prospective Register of Systematic Reviews), hosted by the National Institute for Health Research, University of York, Centre for Reviews and Dissemination (https://www.crd.york.ac.uk/prospero/CRD42020179138). The aim of the protocol was the production of a manuscript, to be published in the *Journal of Clinical Periodontology*, and to inform of the development of an S3-level treatment guideline for stage IV periodontitis at the XVII European Workshop of the European Federation of Periodontology.

The following focused question was phrased: "What is the effect of bridges or dentures versus no treatment in fully or partially edentulous patients affected by stage IV periodontitis in terms of QoL (as measured through psychometric testing) and systemic health (as measured through general disease's incidence and surrogate markers), as reported in randomized and non-randomized controlled clinical trials, case-series, cohort studies, cross-sectional studies, and case–control studies?"

Articles to be included had to follow the following PICOS:

(P) Type of participants: patients with rehabilitation of edentulous areas of at least five teeth.

(I) Type of interventions: any type of prosthetic rehabilitation.

(C) Comparison between interventions: any type of prosthetic rehabilitation compared with no rehabilitation of edentulous areas.

(O) Type of outcome measures: primary OHRQoL outcomes and systemic health outcomes.

(S) Study design: any type of study design with a minimum follow-up of 1 month.

The choice of the loss of five or more teeth was based upon the 2017 World Workshop staging for stage IV periodontitis. However, as none of the studies specifically reported tooth loss due to

periodontitis, the outcomes of this review are derived largely from studies of edentulous spaces of five or more teeth and thus should be interpreted as relevant to any stage of periodontitis. The choice of at least 1-month follow-up was based on the evidence from previous literature indicating that improvements of OHRQoL are already evident after 4 weeks (Jenei et al., 2015).

No time limitations were applied. Only articles in English were included as approved by the workshop organizers due to time constraints.

2.2 | Information sources and search

The electronic search was applied to the Cochrane Oral Health Group specialist trials, MEDLINE via PubMed, and EMBASE (Stefano Gennai) up to April 2020. The strategy used was a combination of MeSH terms and free text words (in dental journals):

Disease: Jaw, Edentulous, Partially[MeSH] OR Jaw, Edentulous [Mesh] OR Mouth, Edentulous[MeSH] OR Anodontia[MeSH] OR Tooth Loss[MeSH] OR Partially Dentate OR Edentulous OR Edent* OR Missing Teeth OR Absent Teeth OR Edentate OR Partial Edentulous OR Hypodontia OR Tooth loss OR periodont*.

AND

Intervention: (Dentures[MeSH] OR Denture, Partial[Mesh] OR Denture, Partial, Removable[Mesh] OR Denture, Partial, Fixed[MeSH] OR Denture, Overlay[MeSH] OR Dental-Prosthesis, Implant-Supported[Mesh] OR Dental Implants[MeSH] OR Denture OR Partial Denture OR Overdenture OR Bridge OR Dental Bridge OR Implant OR (Rehab* AND dental implant* OR Prosthesis) OR tooth-support* OR tooth-support[MeSH] OR full-arch rehab*).

AND

Outcomes: (Oral Health Impact Profile OR OHIP OR Oral Impacts on Daily Performance OR OIDP OR Global Oral Health Assessment Index OR Geriatric Oral Health Assessment Index OR GOHAI OR OHRqL* OR Cognitive* OR systemic inflammation OR inflammatory disease* digestive OR gastr* OR inflammatory biomarkers OR cytokines OR general health OR cognitive OR neuro*).

AND

Study design: (longitudinal study[MeSH Terms] OR randomized controlled trial[MeSH Terms] OR clinical trial[MeSH Terms] OR prospective study[Mesh Terms] OR cohort studies[Mesh Terms] OR case control[MeSH Terms] OR cross sectional [MeSH Terms]).

Hand-search included a complete search of the following Journals:

- *Journal of Periodontology*
- *Journal of Clinical Periodontology*
- *Journal of Dental Research*
- *International Journal of Periodontics & Restorative Dentistry*
- *Journal of Periodontal Research*
- *Journal of Oral Rehabilitation*
- *Journal of Prosthetic Dentistry*
- *International Journal of Prosthodontics*
- *Journal of Prosthodontic Research*
- *Journal of Prosthodontic*
- *Clinical Oral Implants Research*
- *International Journal of Oral and Maxillo-Facial Implants*
- *Implant Dentistry*
- *Clinical Implant Dentistry and Related Research*

Furthermore, bibliographies of all relevant papers and review articles were checked (Larisa Music, Rossana Izzetti, Maria C. Pioli). In addition, authors and experts were contacted to detect other trials or unpublished material or to clarify ambiguous or missing data (Stefano Gennai). Trials databases such as clinicaltrial.gov and other relevant sites were searched.

2.3 | Study selection and data collection

Eligibility assessment was performed through title and abstract analysis and full text analysis. Titles and abstracts of the search results were initially screened by two reviewers (Maria C. Pioli, Rossana Izzetti) for possible inclusion in the review. Reviewers were calibrated for study-screening against another reviewer with experience in conducting systematic reviews (Stefano Gennai). Each round of calibration consisted of a duplicate, independent validity assessment of 20 titles and abstracts from the search. The reviewer had to achieve a consistent level of agreement (κ-score > 0.8; Stefano Gennai calculated the Cohen K-score). In order not to exclude potentially relevant articles, unclear abstracts were included in the full text analysis. Title and abstract analysis was performed in April 2020.

Inclusion criteria for the title and abstract analysis were the following:

- One of the groups consisting of edentulous areas (at least five missing teeth) or with rehabilitation of edentulous areas (at least five missing teeth that received rehabilitation);
- At least 10 patients per group;
- At least 1-month follow-up for all study designs, except for cross-sectional studies;
- Manuscripts published in English.

Exclusion criteria for the title and abstract analysis were the following:

- Subjects with fewer than five lost teeth or with a rehabilitation of less than five teeth;
- Less than 10 patients per group;
- Studies that could not be classified as randomized controlled trials (RCTs), controlled trials (CTs), case-series trials (CSs), cohort studies with retrospective/prospective design, case–control studies, or cross-sectional studies.

Full texts of all possible relevant studies were then obtained for independent assessment by three reviewers against the stated

inclusion criteria (Larisa Music, Rossana Izzetti, Maria C. Pioli). Disagreements were resolved by discussion with an experienced reviewer (Stefano Gennai). Full text inclusion was performed in May 2020 and full text data extraction by mid-June 2020.

A full text article had to follow the inclusion criteria in order to be included and to report at least one of the primary outcomes. The same exclusion criteria were employed for the full text analysis, together with absence of reporting of any of the studied outcomes.

After the final inclusion, data of the included articles were extracted through an ad hoc extraction sheet (Larisa Music, Rossana Izzetti, Maria C. Pioli). If information about the periodontal status of the patients was not reported, the authors were contacted electronically. The reviewers conducted all quality assessments independently.

2.4 | Outcomes measures

The outcomes measures of interest were divided in two areas:

- A. Outcomes concerning OHRQoL:
  - Psychometric testing (Atchison & Dolan, 1990; Slade & Spencer, 1994; Adulyanon et al., 1996);
  - Visual analogue scale (VAS);
  - Symptoms registrations.
- B. Systemic health-related outcomes:
  - Incidence of systemic diseases;
  - Prevalence of systemic diseases;
  - Values of systemic indicators such as biomarkers and organ-function-related indicators.

When data were missing, the authors were contacted. If no reply was given within 2 weeks, the related manuscript was excluded from the meta-analysis. When individual patient data were provided, the average difference was calculated by the reviewers.

2.5 | Risk of bias in individual studies

Risk of bias was evaluated through a process of quality analysis performed by three reviewers (Larisa Music, Rossana Izzetti, Maria C. Pioli).

Quality analysis of RCT, CT, and CS was performed according to the *Cochrane Reviewers' Handbook* (Higgins & Green, 2011), and implied the assessment of six important domains of an RCT:

- Random sequence generation
- Allocation concealment
- Blinding of participants, personnel, and outcome assessors
- Handling of incomplete outcome data
- Selective outcome reporting
- Other sources of bias.

All six included items were finally deemed as adequate, inadequate, or unclear (Higgins et al., 2009).

To accurately assess other sources of bias, the CONSORT guidelines for non-pharmacological treatments (http://www.consort-statement.org) were used with focus on:

- Information concerning the study design
- Source of funding, setting of the study
- Therapist's expertise
- Definition of level analysis
- Calibration
- Statistical methods
- Participants' smoking habits.

The quality of each cohort, case–control study, and cross-sectional study was evaluated according to Newcastle Ottawa Scale (NOS) for Assessing the Quality of Non-randomized Studies (Lo et al., 2014) (http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp).

2.6 | Risk of bias across studies

Heterogeneity between the studies was tested and evaluated through Q and I^2 test. A p-value of the Q-statistic <.1 was defined as an indicator of heterogeneity. The I^2-statistic was used to describe variations across studies due to heterogeneity rather than chance, with I^2 over 75% being considered to indicate substantial heterogeneity (Higgins & Thompson, 2002). A fixed-effects model was used when the heterogeneity among studies was statistically significant; in all other cases, a random-effects model was applied.

2.7 | Summary measures and synthesis of the results

Data were synthesized in evidence tables addressing study characteristics and main conclusions. Data were stratified according to the periodontal status of the patient (studies in which all the patients had suffered from periodontitis vs. studies in which only a sub-sample or an unknown proportion was affected by periodontitis).

In studies reporting on edentulism, data were stratified according to interventional and epidemiological studies and synthesized separately for outcomes on OHRQoL and systemic health-related outcomes.

Decisions on possible meta-analysis were made depending on the availability and similarity of quantitative data. Results were expressed as weighted mean difference (WMD) and 95% confidence interval (CI) for continuous outcomes using both fixed and random models. The patient was the unit of the analysis. Analyses were performed with OpenMeta[Analyst] (http://www.cebm.brown.edu/open_meta/open_meta/open_meta) or other equivalent software for meta-analysis (Stefano Gennai). Meta-analyses were graphically illustrated and summarized with forest plots.

3 | RESULTS

3.1 | Study selection

A total of 1013 unique citations of articles published up to April 2020 were identified for inclusion in the review. Electronic database search retrieved 1008 articles and hand-search retrieved five additional articles (Tables 1 and 2). Seven-hundred and two articles were excluded following the screening of titles and abstracts. Full text of the remaining 311 articles were read, from which 252 articles were further excluded. Fifty-nine articles were included in the final review. Twelve articles met the criteria for inclusion in the meta-analysis (Figure 1). A kappa score >0.8 was obtained among the reviewers in all the phases of title and abstract selection, full text analysis, and data extraction.

3.2 | Study characteristics

3.2.1 | Study design and study population

The study population consisted of 6724 subjects, with a mean age of 65.96 ± 8.12 (range 35–92 years, 55.9% females). Smoking status was reported in nine papers (Dierens et al., 2009; Jofre et al., 2013; Karbach et al., 2015; Ettl et al., 2016; Pozzi et al., 2016; Matthys, Vervaeke, Jacquet, & De Bruyn, 2018; Toia et al., 2019; Zhang et al., 2019; Higuchi et al., 2020), and 20% subjects were reported to be smokers (range 0%–58%). The split in relation to the extent of tooth loss was as follows:

- 30.10% of the sample reported the treatment of complete edentulism.
- In 53.96% of cases, oral rehabilitation was performed either in the maxilla or in the mandible (38.91% unspecified, 13.29% maxilla, 47.89% mandible).
- 15.91% reported treatment of partial edentulism.

The follow-up period varied greatly across the included studies, from 1 month to 14 years.

Overall, the articles included in the review did not mention the cause of tooth loss. A total of 20 responses (34% of the sample) were received and recorded after directly contacting the authors. Seven papers had inadequate information regarding the reasons for tooth loss.

Manuscripts exclusively reporting on a population of patients affected by periodontitis were not found. Some studies reported—either in the manuscript or after contacting the authors—the inclusion of some patients affected by periodontitis (Allen & McMillan, 2003; Dierens et al., 2009; Shigli & Hebbal, 2010; Erkapers et al., 2011; Petricevic et al., 2012; Jofre et al., 2013; Müller et al., 2013; Hoeksema et al., 2017; Ribeiro et al., 2017; McKenna et al., 2018; Reissmann et al., 2018; Zhang et al., 2019; Higuchi et al., 2020).

3.2.2 | Patient-reported outcome measures across studies

The general QoL instruments employed were European Organization for Research and Treatment of Cancer Quality of Life Questionnaire (EORTC QLQ-C30), European Organization for Research and Treatment of Cancer Quality of Life Questionnaire Head and Neck 35 (EORTC QLQ-H&N35), General Health Questionnaire (GHQ), Social Impact Questionnaire (SIQ), Short Form-36 (SF-36), The World Health Organization Quality of Life-BREF (WHOQOL-BREF), General Satisfaction Score (GSS), and EuroQol-5D (EQ-5D).

The oral-health-specific instruments reported in the included studies were Oral Health Impact Profile-14 (OHIP-14), OHIP-20, OHIP-49, OHIP-54, OHIP-EDENT (specific for edentulous subjects), OHIP-EDENT-21, Oral Health Quality of Life-UK (OHQoL-UK), Oral Impact on Daily Performances (OIDP), Dental Impact on Daily Living (DIDL), and Geriatric Oral Health Assessment Index (GOHAI). Patient satisfaction measure was reported as assessed through VAS, Likert scale, or questionnaires of various number of items.

3.2.3 | Systemic health outcome measures across studies

Measures associated with systemic health outcomes concerned cognitive impairment, nutritional status, frailty, and serum markers, measured through Cognitive Dementia Rating Scale (CDR) and Mini Mental Status Examination (MMSE), Mini Nutritional Assessment index (MNA), Groningen Frailty Index (GFI), and changes in serum markers (haemoglobin, albumin, folic acid, vitamin B12, and C-reactive protein), respectively.

Types of intervention

Different types of intervention were reported in the included articles as follows:

- Extension
  - Complete prosthesis (rehabilitation of a completely edentulous dental arch)
  - Partial prosthesis (rehabilitation of a partially edentulous dental arch)
- Fixation
  - Dentures (removable prosthesis)
  - Bridges (fixed prosthesis)
- Abutment type
  - Teeth
  - Implants
    - Bridges on implants
    - Implant-retained prosthesis (placement of two dental implants as a support to overdenture)
    - Implant-supported prosthesis (placement of more than two dental implants as a support to overdenture)
  - Non-tooth-supported or non-implant-supported/retained prosthesis.

TABLE 1 Evidence table of included interventional studies

Author	Setting, funding	Study design	Sample size number, mean age, % of females, % of smokers	Study classification (jaw rehabilitation, type of edentulism, type of rehabilitation)	Pre-interventional status	Reasons for edentulism	Interventions description	Outcomes, follow-up	Study conclusions
Allen et al. (2006)	Dental hospital, Public and industry grants	RCT	1. 45 subjects, 64.5 ± 8.8 years, 71.1% female 2. 46 subjects, 68.5 ± 9.9 years, 73.7% female	Mandible and maxilla, Complete edentulism, Mobile complete conventional dentures in both jaws (2); Implant retained rehabilitation (2 implants) in the maxilla, conventional dentures in the mandible (1)	Completely edentulous maxilla and mandible	NR	1. Mandibular implant-retained overdenture (2 implants) and conventional denture in the upper jaw 2. Conventional dentures in both jaws	OHIP-49, patient satisfaction, 3 months	Upon completion of treatment, both groups reported improvement in oral-health-related quality of life and denture satisfaction. There were no significant post-treatment differences between the groups, but a treatment effect may be masked by the application of "intention to treat" analysis. The OHIP change scores were significantly greater for patients receiving implants than for those who refused them.
Awad et al. (2000)	University, Industry grant	RCT	1. 54 subjects, 33 ≥ 50 years old, 21 subjects <50 years old, 52% female 2. 48 subjects, 29 ≥ 50 years old, 19 subjects <50 years old, 46% female	Mandible, Complete edentulism, Mobile complete implant retained rehabilitation (2 implants)	Completely edentulous mandible, complete dentures	NR	1. Mandibular implant-retained overdenture (2 implants) 2. Conventional overdenture	OHIP-49, 2 months	In summary, the findings from this stratified RCT, conducted with the use of a validated standard assessment tool, suggest that patients who receive implant treatment experience more improvement in their perceived oral health than do patients who receive conventional treatment.
Awad et al. (2014)	University, Industry grant	RCT	1. 104 subjects, 68.8 ± 10.4 years, 62% female 2. 99 subjects, 68.8 ± 10.4 years, 48% female	Mandible, Complete edentulism, Mobile complete implant retained rehabilitation (2 implants) (1) and Conventional complete denture (2)	Completely edentulous mandible	NR	1. Mandibular implant-retained overdenture (2 implants) 2. Conventional denture	OHIP-20, 6 months	Mandibular 2-implant overdentures were more likely than conventional dentures to improve OHRQoL for edentulous patients. Cultural differences were also observed in the impact of implant overdentures on the different domains of the OHIP-20.
Berretin-Felix et al. (2008)	University, NR	CS	15 subjects, 66 years (60–76), 67.7% female	Mandible, Complete edentulism, Fixed complete implant-supported rehabilitation (5 implants)	Completely edentulous maxilla and mandible, complete dentures	NR	Mandibular implant-supported fixed prosthesis (5 implants)	OIDP, OHIP-14, WHOQOL-BREF, 18 months	Scores in the OIDP and OHIP-14 questionnaires were better after dental treatment. The WHOQOL-BREF was less sensitive, confirming the higher reliability of specific questionnaires (focal) compared with general questions in such situations. In conclusion, treatment with implant-supported fixed prostheses improved QL in the elderly; these effects are better detected by specific instruments focused on the subject.
Boven et al. (2020)	University, NR	RCT	1. 25 subjects 60.1 years, 48% female 2. 25 subjects, 63.8 years, 48% female	Maxilla, Complete edentulism, removable complete implant supported rehabilitation (4 implants)	Mandible: completely edentulous with conventional mandibular denture or a two implant-retained overdenture Maxilla: completely edentulous	NR	1. Maxillary implant-supported overdentures (4 implants—bar attachments) 2. Maxillary implant-supported overdentures (4 implants—locator attachments)	OHIP-49, GSS (General Satisfaction Score), 1 year	Maxillary overdentures on four implants retained by bars or locators were compared. Even though both treatment options improved patient satisfaction, bars seem to be particularly beneficial with regard to OHIP-49 sum score. However, clinical indices and scores on separate items of the denture complaints questionnaire and OHIP-49 do not appear to differ.
Cakir et al. (2014)	University, NR	RCT	1. 29 subjects 61.23 ± 10.32 years, 55.1% female 2. 29 subjects, 58.83 ± 9.77, 55.2% female	Mandible, Complete and Partial edentulism, Implant retained overdenture (1), Conventional complete dentures (2), Implant	Partially or completely edentulous mandible for a minimum of 5 years	NR	1. Implant-retained mandibular overdenture (2 implants) 2. Mandibular complete denture	OHQoL-UK, OHIP-14, SF-36, 12 months	A positive influence on oral-health-related QoL was observed in all groups. The QoL values were the most improved in the implant-retained overdenture group. The only significant difference in the domains measured by SF-36 was found for mental health.

(Continues)

TABLE 1 (Continued)

Author	Setting, funding	Study design	Sample size number, mean age, % of females, % of smokers	Study classification (jaw rehabilitation, type of edentulism, type of rehabilitation)	Pre-interventional status	Reasons for edentulism	Interventions description	Outcomes, follow-up	Study conclusions
			3. 29 subjects 54.52 ± 8.78 years, 58.6% female 4. 29 subjects, 57.52 ± 10, 44 years, 48.3% female	supported overdenture (3)			3. Implant-supported three-unit fixed partialdenture (2 implants) 4. partial denture replacing three of the missing teeth (terminal tooth was canine)		
De Carvalho Dias et al. (2016)	University, NR	CS	33 subjects, 59.2 years (39–82), 78.8% female	Mandible and maxilla, Complete edentulism, Conventional complete and partial dentures	Completely edentulous maxilla, partially edentulous mandible	NR	Maxillary complete denture and mandibular partial denture	OHIP-14, masticatory efficiency, 6 months	According to the results of the present study, rehabilitationwith Kennedy class I RPDs and complete dentures did not influence masticatory efficiency but improved oral health-related quality of life.
Dierens et al. (2009)	Private practice, NR	CS	28 subjects, 56.8 years (35–76), 56% female, 28% smokers	Mandible or maxilla, Complete edentulism, Fixed complete implant supported rehabilitation (5–8 implants)	Completely edentulous in the maxilla and mandible	NR, however, authors contacted electronically confirmed that some patients had lost teeth due to periodontitis	Maxillary or mandibular implant-supported fixed prosthesis (5–8 implants)	VAS (patient satisfaction), 1 year	Immediate loading in edentulous jaws yielded a significant immediate improvement of patient satisfaction, in terms of comfort, function and aesthetics, and this increases further with the final reconstruction. The improvement was the highest for eating comfort, which correlates with patients' preoperative needs and demands. Postoperative complications were limited and rated as less serious by patients.
Ellis et al. (2007)	University, NR	RCT	1. 20 subjects, age range 55–85, 74.2 ± 7.29 2. 20 subjects, age range 55–85, 73.1 ± 8.61	Mandible and maxilla, Complete edentulism, Conventional complete denture	Completely edentulous maxilla and mandible	NR	1. New dentures (conventional technique) 2. New dentures (duplication technique)	VAS (patient satisfaction), OHIP-20, 1 month	The provision of new dentures either with a conventional technique or with a duplication technique resulted in an overall improvement in oral health-related quality of life and satisfaction. These improvements were statistically significant for some domains, which varied depending on the technique used for the construction of the new dentures. Neither technique was seen to be superior, which may be a reflection of the patients' treatment expectations at the outset. Patients' reported satisfaction with their dentures and the impact that dentures have on their quality of life may not be useful measures for determining the most appropriate technique for providing new dentures.
Enkling et al. (2017)	University, Industry grant	CS	20 subjects, age range 41–87, 75% female	Mandible, Complete edentulism, Mobile complete implant retained rehabilitation (2 implants)	Completely edentulous mandible for at least 6 months	NR	Mandibular implant-supported overdenture (4 implants)	OHIP-G49, 1 year	In the study, a significant drop in the sum score of the OHIP-49 questionnaire was demonstrated, and thus, an improvement in OHRQoL by the described treatment. The stabilization of a lower complete prosthesis with four narrow-diameter implants was a feasible minimally invasive and economical approach to improve oral function and OHRQoL, especially in elderly patients with limited bone support.

(Continues)

TABLE 1 (Continued)

Author	Setting, funding	Study design	Sample size number, mean age, % of females, % of smokers	Study classification (jaw rehabilitation, type of edentulism, type of rehabilitation)	Pre-interventional status	Reasons for edentulism	Interventions description	Outcomes, follow-up	Study conclusions
Erkapers et al. (2011)	University, NR	CS	51 subjects, 65.78 years, 52.9% female	Maxilla, Complete edentulism, Mobile implant supported rehabilitation (6 implants)	Completely edentulous, atrophic maxilla	NR, however, authors contacted electronically confirmed that some patients had lost teeth due to periodontitis.	Maxillary implant-supported fixed prosthesis (6 implants)	OHIP-49, 1 year	Measurement with the OHIP-49 questionnaire displayed that patient satisfaction increases after treatment with a fixed restoration on implants loaded within 24 h. All seven domains showed a statistically significant improvement posttreatment.
Erkapers et al. (2017)	University, Industry grant	CS	51 subjects, 65.8 years (47–83), 52.9% female	Maxilla, Complete edentulism, Fixed prosthesis on implant (6 implants)	Completely edentulous maxilla for at least 3 months	NR	Maxillary screw-retained metal-acrylic implant bridge (6 implants), the provisional restoration was performed with direct and indirect technique	OHIP-49, 3 years	OHRQoL improved after prosthetic rehabilitation with immediately loaded implants in patients with edentulous atrophic maxillae, and remained 3 years after treatment. Quality of life related to oral health increased regardless of prosthetic complications, status in the opposing dentition or subject's age. These results indicate that patients with edentulous atrophic maxillae can benefit from immediately loaded implant technique.
Ettl et al. (2016)	University, Industry grant	CS	29 oncologic subjects (history of head and neck cancer), 60 years (48–82), 24% female, 58.97% smokers	Mandible or maxilla, Complete edentulism, removable complete implant supported rehabilitation (4–6 implants)	Completely edentulous maxilla or mandible	Mandibulectomy	Maxillary or mandibular implant-supported overdenture (individual bar-retained/telescopic crown or locator-retained) (4–6 implants)	OHIP-14, EORTC QLQ-C30, QLQ-H&N35, 1 year	Implant-based prosthetic rehabilitation improves patients' self-confidence, social integration, and functional quality of life in terms of swallowing, speaking, eating, or irritation by dry mouth.
Fenlon et al. (2002)	University, Industry grant	CS	16 subjects, 56.5 years (32–74), 56% female	Mandible, Complete edentulism, removable complete implant retained rehabilitation (2 implants)	Uncomfortable mandibular conventional denture	NR	Mandibular implant-retained overdenture (2 implants)	GHQ (General Health Questionnaire), 2 years	For patients without implant failures and subsequently provided with implant-retained overdentures, significant functional and psychological benefits were demonstrated.
Harris et al. (2013)	University, Industry grant	RCT	1. 60 subjects 2. 62 subjects 64.4 ± 7.8, 68.03% female	Mandible, Complete edentulism, removable complete conventional dentures (1) implant retained rehabilitation (2 implants) (2)	Completely edentulous mandible, uncomfortable conventional lower denture	NR	1. New conventional complete dentures (CCD) 2. Implant-retained overdentures (IOD) after using new conventional complete dentures for 3 months (2 implants)	OHIP-49, Denture satisfaction questionnaire, 6 months	In conclusion, the findings from this study show that, when controlling for expectancy bias and variability in baseline levels, IODs produce significant increases in patient satisfaction levels, perceived function and oral health-related quality of life compared with those achieved with CCDs.
Heydecke et al. (2005)	University, Public and industry grants	RCT	1. 54 subjects, 50.8 years (35–65) 2. 48 subjects, 51.2 years (35–65)	Mandible, Complete edentulism, removable complete implant retained rehabilitation (2 implants)	Completely edentulous mandible for at least 10 years	NR	Mandibular implant-retained overdentures (2 implants)	OHIP-49, SIQ (Social Impact Questionnaire), 2 months	The reliability of the social impact questionnaire used to assess the influences of mandibular prostheses on social and sexual activity is high. Edentulous subjects restored with conventional complete dentures experience more negative impacts on leisure and sexual activities than subjects restored with mandibular implant overdentures after 2 months. The impact of conventional and implant dentures on social and sexual activities is not fully captured by an existing OHQoL measure, the OHIP.

(Continues)

TABLE 1 (Continued)

Author	Setting, funding	Study design	Sample size number, mean age, % of females, % of smokers	Study classification (jaw rehabilitation, type of edentulism, type of rehabilitation)	Pre-interventional status	Reasons for edentulism	Interventions description	Outcomes, follow-up	Study conclusions
Jofre et al. (2013)	University, Public grant	RCT	1. 15 subjects, 75.3 years (45–90), 66.6% female, 0% of smokers 2. 15 subjects, 75.5 (45–90), 46.6% female, 0% of smokers	Mandible, Complete edentulism, removable complete implant retained rehabilitation (2 implants)	Completely edentulous mandible, unstable conventional mandibular dentures, subjects without temporomandibular disorders	NR, however, authors contacted electronically confirmed that some patients had lost teeth due to periodontitis	1. Mandibular implant-retained overdenture (2 SDIs—small-diameter implants) 2. Non-intervention group (control group) Prior to patients allocation, a specialist in prosthodontics controlled the vertical dimension, relined the prostheses, and created a balanced bilateral occlusal scheme with stable dental contacts	OHIP-EDENT, 1 year	The study's findings indicate that after 1 year, patients wearing mandibular overdentures retained by two minimally invasive splinted SDIs significantly improve their quality of life compared with conventional dentures.
Karayazgan-Saracoglu et al. (2017)	University, NR	RCT	1. 12 oncologic subjects with a history of radiotherapy, 65.5 years (49–81), 75% female 2. 10 oncologic subjects with a history of radiotherapy, 65.5 years (49–81), 20% female	Mandible, Complete edentulism, Mobile and fixed complete rehabilitation, implant supported (1), implant retained (2)	Completely edentulous with marginal mandibulectomy because of squamous cell carcinoma—in the opposite arch the subjects were either completely dentate, partially dentate or edentulous	Mandibulectomy	1. Mandibular implant-retained overdenture (2 implants) 2. Mandibular implant-supported fixed metal-acrylic resin prosthesis (4 implants)	OHIP-EDENT, patient satisfaction (VAS), 6 months	Compared with pretreatment mean values, a statistically significant decrease in mean scores of all OHIP-EDENT values and an increase in VAS scores were found in both groups. After patients were treated, their OHIP-EDENT values in the group with an overdenture prosthesis were higher than those in the group with a fixed metal-acrylic resin prosthesis.
Karbach et al. (2015)	University, Industry grant	RCT (crossover trial)	1. 15 subjects, 61 ± 9 years (51–72), 60% female, 20% of smokers 2. 15 subjects 61 ± 9 years (46–82), 67% female, 20% of smokers	Mandible and maxilla, Complete edentulism, removable complete implant supported and retained rehabilitation	Completely edentulous mandible, in the maxilla the subjects were either completely edentulous, had implant-retained prosthesis or were partially edentulous	NR	1. Mandibular implant-retained overdenture (initially two implants incorporated in the overdenture, afterwards four implants, until the end of the study period) 2. Mandibular implant-retained overdenture (initially four implants incorporated in the overdenture, afterwards two implants, followed by incorporation of four implants again until the end of the study period)	OHIP-G14, VAS, 1 year	A considerable increase in OHRQoL could be seen in all patients after the prosthesis was placed on implants. The number of incorporated implants also influences OHRQoL, with four implants having a statistically significant advantage over two implants.
Kleis et al. (2010)	University, NR	RCT	60 subjects, 64 (46–95) years, 75% female	Mandible, Complete edentulism, removable complete implant retained rehabilitation	55 subjects with a completely edentulous mandible, 5 subjects whose teeth were extracted before implantation	NR (terminal dentition extracted before implantation)	Mandibular implant-retained overdenture with different attachment systems (2 implants)	OHIP-49, 1 year	The OHIP analysis that was conducted on 43 patients showed a significant improvement comparing to the preoperative status and the status 1 year after prosthetic loading. The retention elements did not affect the patients' satisfaction, but they lead to different rates of complications and different needs for prosthetic maintenance after treatment.

(Continues)

TABLE 1 (Continued)

Author	Setting, funding	Study design	Sample size number, mean age, % of females, % of smokers	Study classification (jaw rehabilitation, type of edentulism, type of rehabilitation)	Pre-interventional status	Reasons for edentulism	Interventions description	Outcomes, follow-up	Study conclusions
Knipfer et al. (2014)	University, NR	CS	1. 28 subjects, 64.3 years (44–85), 55% female 2. Control group, 40 subjects 59 ± 12 years	Maxilla, Complete edentulism, Conventional complete denture	Completely edentulous maxilla, complete denture	NR	New complete maxillary denture	OHIP-14, speech intelligibility, 6 months	OHRQoL can be significantly ameliorated through oral rehabilitation concerning complete maxillary dentures in elderly people as well as improvement in speech intelligibility. Speech intelligibility improved significantly after 6 months. However, no significant correlation was found between the OHIP sum score or its subscales to the word accuracy, suggesting that the speech intelligibility enhancement achieved through the fabrication of new complete maxillary dentures might not be in the forefront of the patients' perception of their quality of life.
Limmer et al. (2014)	University, NR	CS	17 subjects, 57.9 years (30–78), 35.3% female	Mandible and maxilla, Complete edentulism, Conventional complete denture and complete implant supported rehabilitation (4 implants)	Completely edentulous maxilla and mandible or with terminal dentition requiring extraction prior to enrollment	NR	Mandibular implant-supported fixed prosthesis (4 implants) and maxillary conventional prosthesis	OHIP-49, 12 months	Substantial and clinically important improvements in OHRQoL were achieved with both conventional dentures and the implant-supported fixed prosthesis.
Marcello-Machado et al. (2018)	University, Public and industry grants	CS	23 subjects, 65.95 years (57–77), 65.5% female	Mandible, Complete edentulism, Mobile complete implant retained rehabilitation (2 implants)	Completely edentulous mandible, complete dentures	NR	Mandibular implant-retained overdenture (2 implants)	OHIP-EDENT, GOHAI, DIDL (Daily Living questionnaire), Masticatory function evaluation, 1 year	Implant-retained overdentures considerably improved both the objective masticatory function as well as the OHRQoL and patients' satisfaction about the treatment. This improvement was already noticeable after 1 month for functional parameters and 3 months for subjective perception.
Matthys et al. (2018)	University, NR	CS	1. 25 healthy subjects, 66.3 years (44–83), 52% female 2. 25 healthy subjects, 66.3 years (44–83), 52% female	Mandible, Complete edentulism, removable complete implant retained rehabilitation (2 implants)	Completely edentulous mandible	NR	Mandibular implant-retained overdenture (2 implants)	OHIP-14, 1 year	The conversion technique of a new CD into a 2IOD significantly improved the OHRQoL for mandibular ridges with adequate bone height and those with low bone height. The OHRQoL remained stable up to 1 year after connection.
Matthys, Vervaeke, Besseler, and De Bruyn (2019)	University, NR	CS	1. 29 healthy subjects 2. 27 healthy subjects 66.3 years (41–82), 41% female, 0% of smokers	Mandible, Complete edentulism, removable complete implant retained rehabilitation	Completely edentulous mandible	NR	1. Mandibular implant-retained overdenture (Cawood–Howell 3–4) 2. Mandibular implant-retained overdenture (Cawood–Howell 5–6) (2 implants)	OHIP-14, 5 years	The implant survival was high, clinical radiographic outcome reports limited bone loss and OHRQoL improved after implant connection and remained stable up to 5 years but was negatively affected by maintenance cost.
Matthys, Vervaeke, Besseler, Doornewaard, et al. (2019)	University, Self-funded	CS	1. 34 healthy subjects 2. 56 healthy subjects 65.8 years (41–83), 38.8% female	Mandible, Complete edentulism, removable complete implant retained rehabilitation (2 implants)	Completely edentulous mandible	NR	1. Ball abutments implant-retained overdenture 2. Stud abutments implant-retained overdenture (2 implants)	OHIP-14, 5 years	Balls and locators yielded stable 5-years implant outcome and improved OHRQoL. For both systems, maintenance and related costs seemed inevitable but for the stud abutment system, this cost negatively influenced the OHIP-14 outcome.

(Continues)

TABLE 1 (Continued)

Author	Setting, funding	Study design	Sample size number, mean age, % of females, % of smokers	Study classification (jaw rehabilitation, type of edentulism, type of rehabilitation)	Pre-interventional status	Reasons for edentulism	Interventions description	Outcomes, follow-up	Study conclusions
McKenna et al. (2018)	University, Geriatric Hospital, Public grant	RCT	1. 44 subjects, 74.1 ± 6.2 years, 55.4% female 2. 45 subjects, 73.9 ± 7 years, 56.7% female	Mandible or maxilla, Partial edentulism, Fixed and removable prosthesis on tooth	A minimum of six remaining natural teeth in both arches	NR, however, it is stated that all patients received standardized dental care to render them dentally fit including extraction of hopeless teeth, restoration of caries and non surgical management of periodontal disease. This suggest that some of them may be patients affected by periodontitis	1. Removable partial dentures (RPD) 2. SDA—Shortened Dental Arch—Resin-bonded bridge	OHIP-14, 2 years	Patients in the SDA Group generally maintained their improvements in OHIP-14 scores throughout the 24 month study period. Patients in the RPD Group recorded initial improvements in OHRQOL but for many, these began to diminish 6 months after treatment. The benefits of functionally orientated treatment appeared to increase over time, particularly for the older, more systemically unwell patient cohort.
Müller et al. (2013)	University, Industry grant	RCT	1. 16 subjects, 85 ± 6.19 years, 56.2% female 2. 18 subjects, 84.1 ± 5.55 years, 77.8% female	Mandible, Complete edentulism, removable complete implant retained rehabilitation (2 implants)	Completely edentulous mandible	NR, however, authors contacted electronically confirmed that some patients had lost teeth due to periodontitis	1. Mandibular implant-retained overdenture (2 implants) 2. Denture relining	OHIP–EDENT, patient satisfaction (VAS), MNA (Mini Nutritional Assessment), BMI, Blood markers (haemoglobin, albumin, folic acid, vitamin B12, and C-reactive protein), 1 year	IODs proved more stable, and participants in the intervention group demonstrated significantly higher denture satisfaction as well as an increased oral health–related quality of life compared to the control group. The inconsistent findings in BMI, MNA, and blood markers reflect that nutritional intake is complex and not solely determined by the dental state.
Petricevic et al. (2012)	University, Public grant	RCT	1. 64 subjects, 46.5 ± 11.6 years, 43.8% female 2. 38 subjects, 57.63 ± 14.39, 63.2% female	Mandible and maxilla, Partial edentulism, Fixed prosthesis on implant (1) and tooth (2)	Partially edentulous in the posterior dental regions in either maxilla or mandible	NR, however, authors contacted electronically confirmed that some patients had lost teeth due to periodontitis	1. Implant-supported fixed partial dentures (IFPD) 2. Tooth-supported fixed partial dentures (FPD)	OHIP-49, 3 years	Within the limitations of the study, both prosthodontic treatment options showed significant improvement of the patient's OHRQoL during the first 3-week period and a further improvement in the next 3-year period. The FPD treatment improved OHRQoL equally in both age groups (≤60, >60), while the IFPD treatment improved oral health more in older patients.
Pozzi et al. (2016)	University, NR	CS	18 subjects, 65.4 years (58–73), 61.1% female, 11.1% of smokers	Mandible or maxilla, Complete edentulism, removable complete implant retained rehabilitation (4 implants)	Completely edentulous maxilla and mandible, subjects with conventional dentures	NR	Maxillary or mandibular or both implant-supported overdenture (4 implants)	OHIP-21, 1 year	Oral health-related quality of life significantly improved in all participants.
Reissmann et al. (2018)	University, Industry grant	CS	20 subjects, 66.9 ± 10.7 years, 75% female	Mandible, Complete edentulism, removable complete implant supported rehabilitation (4 implants)	Completely edentulous mandible for at least 6 months, wearing complete dentures	NR, however, authors contacted electronically confirmed that some patients had lost teeth due to periodontitis	Mandibular implant-supported overdentures (4 NDIs—narrow-diameter implants)	OHIP-49, 5 years	This study suggests that four immediately loaded narrow-diameter implants for the support of conventional CD in edentulous patients with substantially impaired OHRQoL may lead to a long-lasting treatment-induced improvement in OHRQoL.

(Continues)

TABLE 1 (Continued)

Author	Setting, funding	Study design	Sample size number, mean age, % of females, % of smokers	Study classification (jaw rehabilitation, type of edentulism, type of rehabilitation)	Pre-interventional status	Reasons for edentulism	Interventions description	Outcomes, follow-up	Study conclusions
Schuster et al. (2017)	University, Public and industry grants	CS	25 subjects	Mandible, Complete edentulism, removable complete implant retained rehabilitation (2 implants)	Completely edentulous mandible, conventional complete dentures	NR	Mandibular implant-retained overdentures (2 implants)	Dental Impact on Daily Living (DIDL), OHIP-EDENT, GOHAI, 3 months	Elderly conventional CD wearers reported major improvements in OHRQoL 3 months after the instalment of IMO, with main improvements observed in the functional aspects of the prostheses and pain perception. ES calculations show that the most important improvements occurred in the chewing and eating domain of the DIDL questionnaire, in the pain and discomfort domain of the GOHAI questionnaire, and the physical pain domain of the OHIP-EDENT questionnaire.
Shigli and Hebbal (2010)	University, Self-funded	CS	35 subjects	Mandible and maxilla, Complete edentulism, Conventional complete dentures	Completely edentulous maxilla and mandible	NR, however, authors contacted electronically confirmed that some patients had lost teeth due to periodontitis	New conventional complete dentures	GOHAI, 1 month	A statistically significant difference was observed for medication used to relieve pain or discomfort, being worried or concerned and for limiting the kinds or amounts of food because of problems with their teeth or dentures. Factors such as difficulty with biting or chewing, limiting contacts with people, being pleased or happy with the looks and feeling nervous or self-conscious because of problems with teeth, gums or dentures also showed a statistically significant difference. When an overall mean was considered, the difference between pre and post-denture insertion scores was highly significant.
Toia et al. (2019)	University, Self-funded and Industry grant	CS	40 subjects, 69 ± 9.5 years, 48% female, 10% of smokers	Mandible or maxilla, Complete edentulism, removable complete implant supported rehabilitation (8–4 implants)	Completely edentulous maxilla or mandible, non-specified dentures	NR	Full-arch, implant-supported overdenture in the maxilla or mandible, anchored on two milled bars based on a friction retention system (4–8 implants)	OHIP-14, 2 years	In conclusion, the study suggested that the procedure achieved excellent results in terms of clinical outcomes and patient satisfaction.
Tõrres et al. (2019)	University, NR	CS	32 subjects, 60.2 years	Mandible and maxilla, Complete edentulism, Conventional dentures	Completely edentulous maxilla and mandible, complete dentures	NR	New conventional dentures	OHIP-EDENT, masticatory efficiency, 1 year	According to the results of the study, denture quality significantly improved patients' oral health related QoL; however, insertion of new dentures did not influence masticatory efficiency.
Veyrune et al. (2013)	University, Self-funded	CS	14 subjects, 10 women (71.43%) 62.9 years; 4 men 65 years	Maxilla or mandible, Complete edentulism, Fixed supported denture (4–8 implants)	Patients with terminal dentition up for extraction in the maxilla or mandible	NR	Maxillary or mandibular full-arch fixed prosthesis with immediate loading (4–8 implants)	GOHAI, mastication efficiency, 6 months	Compared with the preoperative values, the mean GOHAI scores were significantly increased after immediate loading fixed arch prosthesis rehabilitation in all the functional, comfort, and psychosocial fields that make up the GOHAI-Add score
Wolfart et al. (2005)	University, Public grant	RCT	1. 17 subjects, 62 ± 10 years 2. 13 subjects, 62 ± 10 years	Mandible or maxilla, Partial edentulism, removable partial tooth supported rehabilitation	Partially edentulous maxilla or mandible, all molars missing and the presence of at least both canines and one premolar in each quadrant	NR	1. Partial dentures including molar replacement 2. Retainment of a premolar occlusion—cantilevered FDP	OHIP-49, temporomandibular disorders RDC (Research Diagnostic Criteria) questionnaire, 12 months	Within both treatment concepts, an improvement of OHRQoL was achieved.

(Continues)

TABLE 1 (Continued)

Author	Setting, funding	Study design	Sample size number, mean age, % of females, % of smokers	Study classification (jaw rehabilitation, type of edentulism, type of rehabilitation)	Pre-interventional status	Reasons for edentulism	Interventions description	Outcomes, follow-up	Study conclusions
Wolfart et al. (2014)	University, NR	RCT	1. 109 healthy subjects, 59.3 ± 11.2 years, 45% female 2. 106 healthy subjects, 59.6 ± 10.3 years, 54.7% female	Mandible and maxilla, Partial edentulism, removable and fixed partial tooth supported rehabilitation	Partially edentulous in maxilla and mandible, all molars missing and the presence of at least both canines and one premolar in each quadrant	NR	1. Partial dental prostheses (RPDP) with molar replacement 2. Shortened dental arch (SDA)—cantilevered FDP	OHIP-49, 5 years	Within both treatment concepts, a similar improvement of OHRQoL was achieved although the treatment with a RPDP required a slightly longer adaptation period.
Yamada et al. (2015)	University, Industry grant	CS	50 subjects, 56 years (37–74), 44% female	Maxilla, Complete edentulism, Fixed complete implant supported rehabilitation (4–6 implants)	Completely edentulous maxilla	NR	Maxillary implant-supported complete-arch fixed prosthesis (4–6 implants)	OHIP-J54, 1 year	OHIP-J scores improved significantly after insertion of the provisional prostheses and after delivery of the definitive prostheses, indicating the effectiveness of the employed method in improving oral health-related quality of life.
Yamamoto and Shiga (2018)	University, NR	CS	30 subjects, 74.7 years (68–82), 50% female	Mandible and maxilla, Complete edentulism, Conventional complete denture	Completely edentulous maxilla and mandible	NR	New complete dentures	OHIP-J49, 3 months	To clarify the relationship between masticatory performance and OHRQoL, the glucose extraction during chewing gummy jelly was analysed, as well as the answers to the OHIP-J49 questionnaire. The results suggested that masticatory performance and OHRQoL are significantly improved after treatment and that there is a close relationship between the two.
Zembic et al. (2019)	University, Self-funded	CS	21 subjects, 63 years (52–81)	Maxilla, Complete edentulism, removable complete implant retained rehabilitation (2 implants)	Completely edentulous maxilla, conventional complete dentures	NR	Maxillary implant-retained overdentures (two implants)	OHIP-20, patients' satisfaction (VAS,) 4 years	Within the limitations of this study, considering an unequal distribution of two overdenture designs (with full and reduced palatal coverage), as well as a rather small number of patients, maxillary implant-retained overdentures on two implants appeared to have a stable treatment effect over a 4-year period.
Zhang et al. (2019)	University, NR	CS	80 subjects 71.3 ± 6 years, 63.8% female., 20% of smokers	Mandible, Complete edentulism, removable complete implant retained rehabilitation (2 implants) and Conventional complete denture	Completely edentulous mandible	NR, however, authors contacted electronically confirmed that some patients had lost teeth due to periodontitis	Subjects were provided with new mandibular conventional dentures. Following a period of 3 months, subjects who were still dissatisfied with their dentures were provided with mandibular implant-retained overdenture (2 implants)	Patient complaint and patient satisfaction questionnaires, 5 years	The study showed two-implant-supported mandibular overdentures to be a reliable and effective treatment modality for the fully edentulous patient who has unsatisfactory experience with previous complete dentures. Mandibular IOD significantly improved patient satisfaction as well as reduced patient complaints and PROMs achieved after the placement of IOD remained stable for at least 5 years.

Abbreviations: 2IOD, two-implant overdenture; BMI, body mass index; CD, complete denture; CS, case series; DIDL, Dental Impact on Daily Living; FPD, fixed partial denture; GOHAI, General Oral Health Assessment Index; GSS, General Satisfaction Score; IFPD, implant-supported fixed partial dentures; IMO, implant mandibular overdenture; IOD, implant overdenture; MNA, Mini Nutritional Assessment; NR, not reported; OHIP, Oral Health Impact Profile; OHIP-EDENT, Oral Health Impact Profile for edentulous patients; OHQoL-UK, United Kingdom Oral Health-related Quality of Life; OHRQoL, Oral Health-Related Quality of Life; OIDP, Oral Impact on Daily Performance; PROMs, patient-reported outcome measures; QoL, quality of life; RCT, randomized controlled trial; RDC, research diagnostic criteria; RPD, removable partial dentures; RPDP, removable partial dental prosthesis; SDA, shortened dental arch; SDIs, small-diameter (mini) implants; SIQ, Social Impact Questionnaire; VAS, visual analogic scale; WHOQOL-BREF, the World Health Organization Quality Of Life Brief Version.

TABLE 2 Evidence table of included epidemiological studies

Author	Setting, funding	Study design	Sample size number, mean age, gender, % of females, % of smokers	Study classification (jaw rehabilitation, type of edentulism, type of rehabilitation)	Pre-interventional status	Reasons for edentulism	Interventions	Outcomes, follow-up	Study conclusions
Alfadda and Attard (2017)	University, NR	Cohort study	1. 35 subjects, 64.1 ± 10.6 years 2. 40 subjects, 57.72 ± 10.47 years	Mandible, Complete edentulism, removable complete implant supported rehabilitation (2–4 implants)	Completely edentulous mandible	NR	1. Mandibular implant-supported overdenture (4 implants)2. Mandibular implant-retained overdenture (2 implants)	OHIP-20, 14 years	The results indicated an improvement in the global and subscale scores between the baseline and implant insertion levels. No significant changes were observed when the scores were compared with those at the 1- and 5-year recalls. However, the 14-year scores were significantly higher than those at the 5-year recall. The results clearly demonstrate an increase in the OHIP scores, signifying a worsening of the patients' self-reported quality of life. Subscale analysis indicated that the decrease in the quality of life scores was driven by the functional related scores, which were significantly higher at the 14-year recall.
Allen et al. (2001)	University, Public and industry grant	Cohort study	1. 20 subjects, 56.19 years, 85% female 2. 20 subjects, 60.15 years, 55% female 3. 35 subjects, 65.06 years, 74.3% female	Mandible and maxilla, Complete edentulism, Conventional complete denture, removable implant retained rehabilitation	Completely edentulous maxilla and mandible	NR	1. Subjects requested implants to stabilize the denture in the mandible. Received implant-retained mandibular overdenture and conventional maxillary denture 2. Subjects requested implants to stabilize the denture in the mandible. Received conventional dentures in both jaws 3. Subjects requested and received conventional dentures in both jaws	OHIP-49, satisfaction score (Likert scale), 3 months	Before treatment, satisfaction with complete dentures was low in all 3 groups. Subjects requesting implants had high expectations for implant-stabilized prostheses. Improvement in denture satisfaction and OHIP scores was reported by all 3 groups after treatment. Subjects who received their preferred treatment reported a much greater improvement than the group that has not. Preoperative expectation levels did not appear to influence satisfaction with the outcomes of implant therapy in IG subjects. The OHIP appears useful in identifying patients likely to benefit from implant-stabilized prostheses.
Allen et al. (2003)	University, NR	Cohort study	1. 26 subjects, 58.7 years, 88.5% female 2. 22 subjects, 60.2 years, 54.5% female	Mandible and maxilla, Complete edentulism, Conventional complete denture, removable implant	Completely edentulous maxilla and mandible	NR, however, authors contacted electronically confirmed that some patients had	1. Subjects who requested and received dental implants to retain a complete prosthesis 2. Subjects who requested implants to retain a complete prosthesis, but	OHIP-49, SF-36, satisfaction score (Likert scale), undefined follow up	Following treatment, subjects who received implant-retained prostheses reported a significant improvement in satisfaction and health-related quality of life, as did subjects who requested and received conventional dentures.

(Continues)

TABLE 2 (Continued)

Author	Setting, funding	Study design	Sample size number, mean age, gender, % of females, % of smokers	Study classification (jaw rehabilitation, type of edentulism, type of rehabilitation)	Pre-interventional status	Reasons for edentulism	Interventions	Outcomes, follow-up	Study conclusions
			3. 35 subjects, 65.1 years, 74.3% female 4. 30 subjects, 58.7 years, 30% female	retained rehabilitation		lost teeth due to periodontitis	received a conventional prosthesis 3. Edentulous subjects requesting replacement of their complete dentures by conventional means 4. Dentate subjects		Subjects who requested implants, but received conventional dentures, reported little improvement in denture satisfaction and only modest improvement in their quality of life. None of the denture wearing subjects reported health-related quality of life that was as good as that of dentate subjects.
El Osta et al. (2017)	University, NR	Cohort study	1. 35 subjects 70.01 ± 7.89 years, 42.9% female 2. 16 subjects 68.05 ± 5.50 years, 50% female	Mandible and maxilla, Complete and Partial edentulism, Conventional complete denture (1), removable or fixed implant supported rehabilitation	Completely or partially edentulous	NR	1. Complete dentures 2. Implant-supported fixed or dentures	GOHAI, ADL (Activity of Daily Living), MME Mini Mental Exam, Mini-Nutritional Assessment (MNA) Index, 6 months	The study has shown an enhancement in the quality of life and the nutritional status for implant supported-prostheses compared to conventional dentures.
Fillion et al. (2013)	University, Grants	Cohort study	24 subjects, 16.7% less than 50 years old, 16.7% 50 to 60 years old, 66.6% more than 60, 62.5% female	Not a specific jaw reported, Complete edentulism, removable or Fixed complete implant retained rehabilitation	Edentulous	NR	Fixed or Retained Full Prostheses	GOHAI, 15 months	OHRQoL was globally improved after oral treatment by implants. The change in the GOHAI score was greater for the patients with the fewest teeth, and the best improvement was noted for complete treatment ($p < .001$; Effect size = 0.36) compared with single tooth implants ($p < .001$; effect size = 0.13) and fixed partial dentures ($p < .001$; effect size = 0.27).
Fonteyne et al. (2019)	University, Industry grant	Cohort study	30 subjects, 62.6 ± 9.0 years, 43% female	Maxilla, Complete and Partial edentulism, removable complete implant retained rehabilitation	Completely edentulous maxilla (either with or without a complete prosthesis) Partially edentulous or fully dentate mandible (a natural dentition, a combination of natural teeth and partial prosthesis)	NR	Mini-dental implant-retained overdentures in the maxilla	VAS (satisfaction total, speech satisfaction), OHIP-14, 4 months	The OHIP total score was high (21.97) pre-operatively, and this is also reflected in the scores on the first question in the domain "functional limitation". With the provisional denture, the OHIP total score decreased as well (16.93). In the last stage of the treatment, the average total OHIP score decreases to 8.23.

(Continues)

TABLE 2 (Continued)

Author	Setting, funding	Study design	Sample size number, mean age, gender, % of females, % of smokers	Study classification (jaw rehabilitation, type of edentulism, type of rehabilitation)	Pre-interventional status	Reasons for edentulism	Interventions	Outcomes, follow-up	Study conclusions
Ha et al. (2012)	University, Self-funded	Cohort study	1. 262 subjects, 72.87 years (65–93), 66.7% female 2. 178 subjects, 74.72 years (65–92), 71.9% female	Location not reported, Complete and Partial edentulism, removable partial denture (1), Complete Conventional Denture (2)	Partially or completely edentulous, 249 subjects (56.7%) used denture at baseline, 190 subjects (43.3%) did not use denture at baseline	NR	1. RPD (partial denture) 2. CD (complete denture)	OHIP-14 K, self-reported oral health status, satisfaction with receiving dentures and the improvement in self-perceived oral health after provision of dentures, 3 months	The study revealed considerable improvement in OHRQOL among poor elderly people after NDS (National Denture Service that provided prosthodontics treatment). Satisfaction with provision of dentures was associated with improvement in the OHRQOL.
Higuchi et al. (2020)	University, NR	Cohort study	110 subjects, 61.7 ± 63 years, 54.5% female, 20.9%	Maxilla, Complete edentulism, Complete implant supported rehabilitation (3 implants)	Completely edentulous mandible	NR, however, authors contacted electronically confirmed that some patients had lost teeth due to periodontitis	Mandibular implant-supported full-arch prosthesis (3 implants)	OHIP-EDENT-21, patient satisfaction, 1 year	The 1-year results suggested that the proposed three-implant–supported standardized treatment concept can improve function and patient quality of life.
Hoeksema et al. (2017)	University, Public grant	Cross-sectional	1. 104 subjects, 80 years (76–85), 58% female 2. 521 subjects, 81 years (78–85), 60% female	Not a specific jaw reported, Partial, and complete edentulism, removable Implant supported rehabilitation		NR, however, authors contacted electronically confirmed that some patients had lost teeth due to periodontitis	1. Implant-supported overdenture 2. Edentulous	Activity of Daily Living (ADL), Number of chronic conditions, Case complexity (complex care needs, frail, robust), EuroQoL-5D	Elderly with complex care needs experience significantly more oral health problems and are more often edentulous than robust elderly. Moreover, elderly with remaining teeth and elderly with implant-supported overdentures reported less frailty and better QoL.
Jabbour et al. (2012)	University, Industry	Cohort study	1. 68 subjects, 71 ± 4.5 years, 48.5% female 2. 85 subjects, 71 ± 4.5 years, 54% female	Mandible, Complete edentulism, Conventional complete denture (1), removable implant retained rehabilitation (2 implants) (2)	Completely edentulous	NR	1. Conventional complete denture 2. Mandibular implant-retained overdenture (two implants)	OHIP-20, 2 year	Within group comparisons revealed significant decreases in total OHIP scores ($p < .001$) and all its domains ($p < .01$) from baseline to first and second year follow-up for both treatment groups. In conclusion, mandibular two-implant retained overdentures maintained a better OHRQoL in the long-term than conventional dentures.

(Continues)

TABLE 2 (Continued)

Author	Setting, funding	Study design	Sample size number, mean age, gender, % of females, % of smokers	Study classification (jaw rehabilitation, type of edentulism, type of rehabilitation)	Pre-interventional status	Reasons for edentulism	Interventions	Outcomes, follow-up	Study conclusions
Jones et al. (2003)	University, Grants	Cross-sectional	1. 91 subjects, 66.1 years 2. 176 subjects, 65.3 years 3. 79 subjects, 68.1 years 4. 140 subjects, 66.3 years	Location not reported, Complete and Partial edentulism		NR	1. 11–24 teeth with denture 2. 11–24 teeth no denture 3. 1–10 teeth with denture 4. 0 teeth with denture	OH-1 (self-report of oral health), OHQOL, GOHAI, OHIP-49, DELTA	Tooth loss and denture wearing is related to decrements in patient-assessed oral health.
Khan et al. (2019)	University, NR	Cohort study	1. 37 subjects, 57.4 ± 13.1, 24% female 2. 16 subjects, 57.4 ± 13.1, 9% female 3. 27 subjects, 57.4 ± 13.1, 15% female	Mandible and maxilla, Partial edentulism, Partial removable denture	Partially edentulous maxilla and mandible, variously distributed posterior shortened and interrupted arches, Kennedy class I, II and III	NR	partial denture 1. Cobalt-chrome clasp-retained RPDPs Kennedy class I 2. Cobalt-chrome clasp-retained RPDPs Kennedy class II3. Cobalt-chrome clasp-retained RPDPs Kennedy class III	OIDP, patient satisfaction, general and oral health, 6 months	Overall, significant reductions of negative impacts were observed following treatment with dentures, across the Kennedy groups, with respect to improved function, satisfaction, and oral health-related QoL.
Kurushima et al. (2015)	University, NR	CS	1. 17 subjects, 74.9 ± 6.0, 45.2% female 2. 14 subjects, 74.9 ± 6.0, 45.2% female	Location reported, Complete edentulism, Conventional complete denture	Completely edentulous	NR	1. Severe case of edentulism treated with complete dentures 2. Moderate case of edentulism treated with complete denturesSevere or moderate according the Index of case difficulty.	OHIP-EDENT, pre and post-treatment (not defined)	OHIP scores improved in all participants, however this improvement was statistically significant only in the severe group. The improvement in food acceptance was also greater in the severe group than in the moderate group.
Ribeiro et al. (2017)	University, Public grant	CT	1. 17 subjects with Parkinson disease, 69.4 ± 4.7 years, 47% female 2. 17 healthy subjects, 70.7 ± 4.7 years, 41% female	Mandible and maxilla, Complete and Partial edentulism, Complete and Partial conventional rehabilitation	Completely or partially edentulous, using or not using unsatisfactory CD and/or RPD according to the Vigild criteria	NR, however, it is stated that in partially dentate subjects basic periodontal, restorative and endodontic therapy was provided before rehabilitation if needed, suggesting some may be patients affected by periodontitis	Partial or complete dentures in the maxilla, mandible or both	OHIP-49, masticatory efficiency, 2 months	1. Oral rehabilitation with new dental prostheses improved OHRQoL and Masticatory Efficiency in elders with and without PD. 2. However, ME in elders with PD remained below control levels.

(Continues)

TABLE 2 (Continued)

Author	Setting, funding	Study design	Sample size number, mean age, gender, % of females, % of smokers	Study classification (jaw rehabilitation, type of edentulism, type of rehabilitation)	Pre-interventional status	Reasons for edentulism	Interventions	Outcomes, follow-up	Study conclusions
Saarela et al. (2014)	University, Public grant	Cross-sectional	1. 614 subjects, with Diabetes, Coronary heart disease, Dementia, Depression, psychiatric disease, years 84.7 ± 7.8, 81.7% female 2. 94 subjects, with Diabetes, Coronary heart disease, Dementia, Depression, psychiatric disease, 82 ± 7.8 years, 59.8% female	Mandible and maxilla, Complete edentulism		NR	1. Dentures 2. Totally edentulous subjects	Mini Nutritional Assessment (MNA), CDR Memory score, CDR personal care score, BMI, Oral symptoms	Pureed or soft food consumption was reported most frequently in edentulous subjects without dentures.
Saarela et al. (2016)	University, Public grant	Cross-sectional	1 .134 subjects, 84.6 ± 7.2 years, 84.3% female 2. 28 subjects, 84.5 ± 7.1 years, 74% female	Mandible and maxilla, Partial edentulism		NR	1. Dentures 2. Edentulous subjects	Mini Nutritional Assessment (MNA), Cognitive impairment, Impaired ADLc, Charlson's comorbidity index	Malnutrition and inadequate protein and vitamin C intakes were very common and were associated with dentition among older people in assisted living facilities. Assessment of dental status and tailored nutritional support should be part of good nutritional care in long-term care.
Shin et al. (2019)	University, Public grant	Cross-sectional	1. 76 subjects 2. 143 subjects	Location not reported, Complete edentulism, removable complete conventional denture		NR	1. Complete denture 2. Edentulous	Cognitive impairment	Data showed that non-rehabilitated lost teeth were independently associated with cognitive impairment. Hence, rehabilitation of the lost teeth could be important for the maintenance of cognitive function.

Abbreviations: ADL, Activity of Daily Living; BMI, body mass index; CD, complete denture; CDR, clinical dementia rating questionnaire; CS, case series; DIDL, dental impact on daily living; GOHAI, general oral health assessment index; IOD, implant overdenture; MME, Mini Mental Exam; MNA, mini nutritional assessment; NR, not reported; OH-1, self-report of oral health; OHIP, oral health impact profile; OHIP-EDENT, oral health impact profile for edentulous patients; OHQoL, oral health quality of life; OIDP, oral impact on daily perform; QoL, quality of life; RCT, randomized clinical trial; RPD, removable partial dentures; SF, satisfaction score; VAS, visual analogic scale.

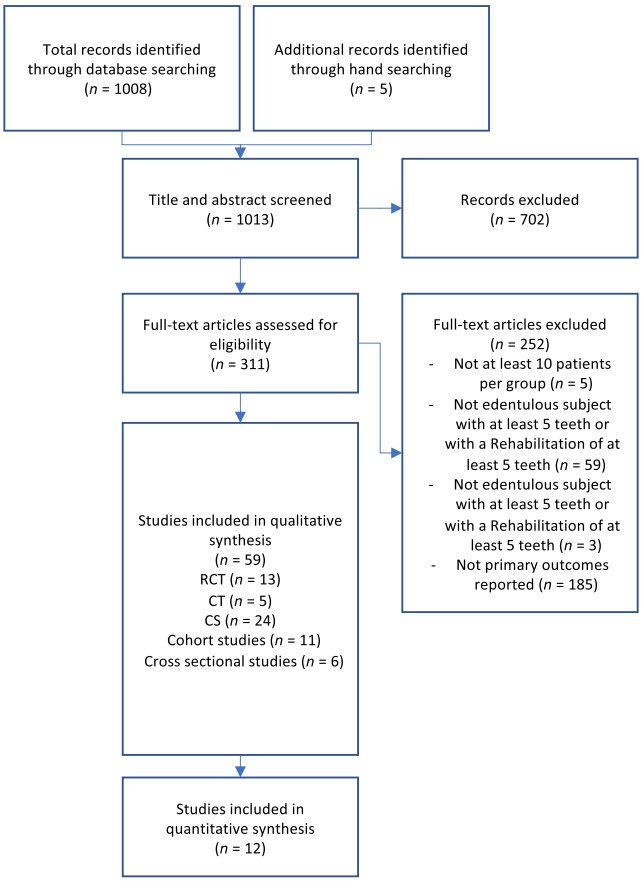


FIGURE 1 Flow of the studies during the review. CS, case series; CT, controlled trial; RCT, randomized controlled trial [Colour figure can be viewed at wileyonlinelibrary.com]

3.3 | Results of individual studies and synthesis of results in subjects affected by periodontitis ($n = 13$)

In total, 13 studies formally included subjects with a history of periodontitis (Allen & McMillan, 2003; Dierens et al., 2009; Shigli & Hebbal, 2010; Erkapers et al., 2011; Petricevic et al., 2012; Jofre et al., 2013; Müller et al., 2013; Hoeksema et al., 2017; Ribeiro et al., 2017; McKenna et al., 2018; Reissmann et al., 2018; Zhang et al., 2019; Higuchi et al., 2020). Adequate information on the stage of the disease, the reasons for tooth loss, and the exact number of patients affected by periodontitis was not reported in these studies. All treatment modalities yielded an improvement in OHRQoL scores, as measured through OHIP-14 and OHIP-49 questionnaires.

3.3.1 | Partial edentulism ($n = 4$)

Four studies described the rehabilitation of partially edentulous subjects (Petricevic et al., 2012; Hoeksema et al., 2017; Ribeiro et al., 2017; McKenna et al., 2018), employing different oral rehabilitation modalities (partial dentures, resin-bonded bridges, and bridges on implants) in the posterior edentulous region.

3.3.2 | Complete edentulism ($n = 9$)

Nine studies reported the rehabilitation of complete edentulism (Allen & McMillan, 2003; Dierens et al., 2009; Shigli & Hebbal, 2010; Erkapers et al., 2011; Jofre et al., 2013; Müller et al., 2013; Reissmann et al., 2018; Zhang et al., 2019; Higuchi et al., 2020). Implant-retained/supported rehabilitations were provided in seven studies (Dierens et al., 2009; Erkapers et al., 2011; Jofre et al., 2013; Müller et al., 2013; Reissmann et al., 2018; Zhang et al., 2019; Higuchi et al., 2020), whereas one study (Allen & McMillan, 2003) compared the outcomes of implant-retained rehabilitation versus conventional dentures. One study (Shigli & Hebbal, 2010) exclusively reported oral rehabilitation through complete dentures.

3.3.3 | Meta-analysis ($n = 3$)

Meta-analysis was performed for OHIP-49 and included three articles (Petricevic et al., 2012; Ribeiro et al., 2017; Reissmann et al., 2018). The WMD of the severity of OHIP-49 between baseline and after treatment was 36.86 (95% CI: [19.62, 54.10], $p < .01$, and $I^2 = 95.60\%$) (Figure 2).

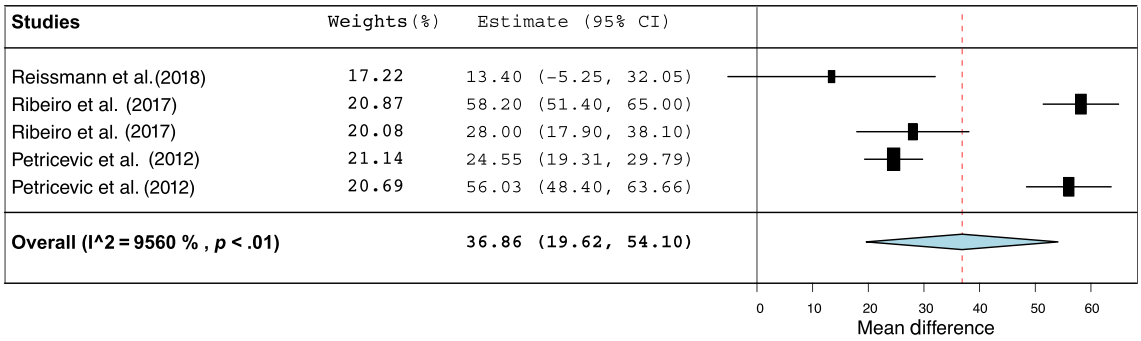
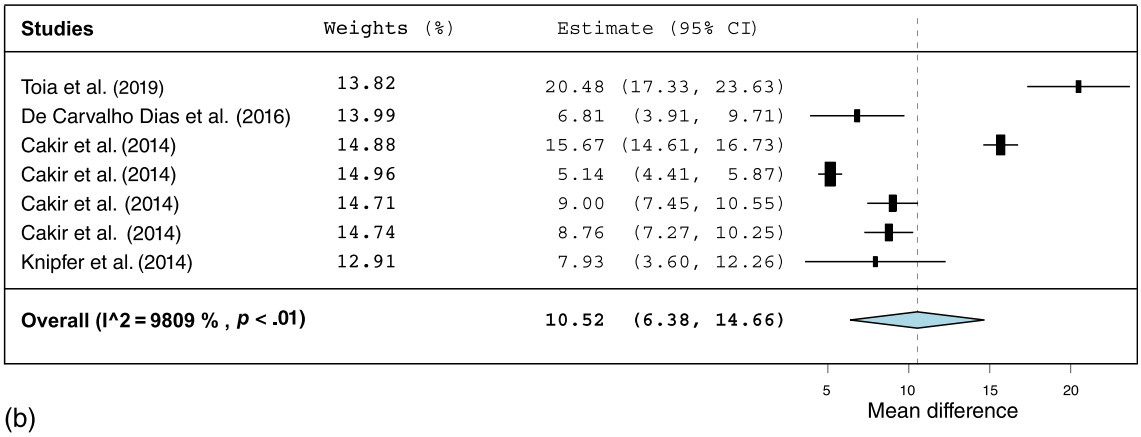
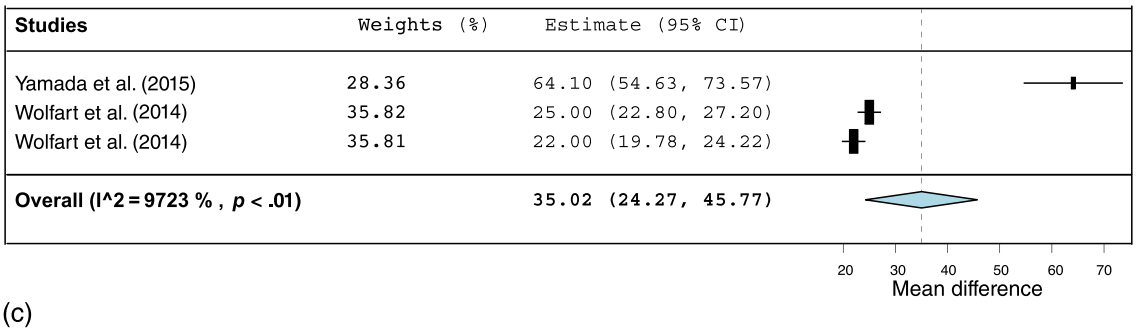


FIGURE 2 Forest plot from fixed effects of meta-analysis evaluating the difference between baseline and post-treatment values in Oral Health Impact Profile 14 after oral rehabilitation in subjects affected by periodontitis (weight mean difference, 95% confidence interval [CI]) [Colour figure can be viewed at wileyonlinelibrary.com]

(a)



(b)



(c)

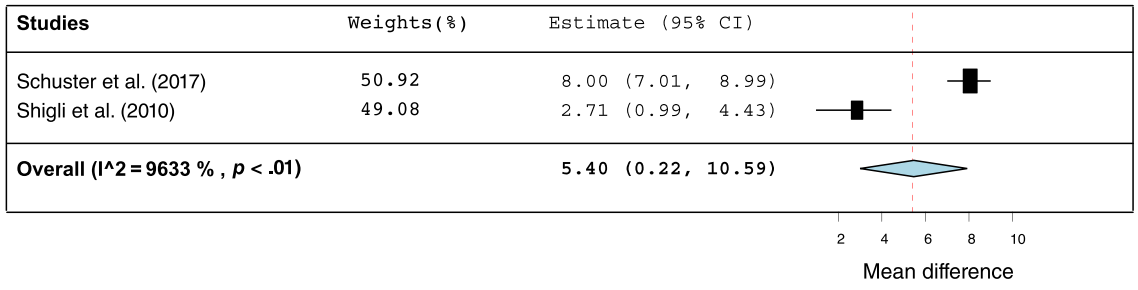


FIGURE 3 Forest plot from fixed effects of meta-analysis evaluating the difference between baseline and post-treatment values in Oral Health Impact Profile 14 (a), Oral Health Impact Profile 49 (b), General Oral Health Assessment Index (c) after oral rehabilitation (weight mean difference, 95% confidence interval [CI]) [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 3 Summary of risk of bias in individual interventional studies

Author, year	Study design	Setting	Funding	Randomization	Allocation concealment	Assessor blinding	Operators blinding	Missing outcome data reported	Missing outcomes were balanced among groups	Reasons for drop out clearly specified	Selective outcome reporting	Therapist experience	Statistical method	Sample size estimation	Examiner calibration
Allen et al. (2006)	RCT	Dental hospital	Public grant/ industry	Adequate	Unclear	Inadequate	Inadequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Unclear
Awad et al. (2000)	RCT	University	Industry	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Adequate	Adequate	Adequate	Adequate	Adequate	Unclear
Awad et al. (2014)	CT	University	Industry	NA	NA	Inadequate	Inadequate	Adequate	Adequate	Adequate	Adequate	Unclear	Adequate	Adequate	Unclear
Boven et al. 2019	RCT	University	NR	Unclear	Unclear	Unclear	Unclear	Adequate	Adequate	Adequate	Adequate	Unclear	Adequate	Adequate	Unclear
Cakir et al. (2014)	RCT	University	NR	Adequate	Unclear	Inadequate	Inadequate	Adequate	Adequate	Adequate	Adequate	Unclear	Adequate	Adequate	Unclear
Ellis et al. (2007)	CT	University	NR	NA	NA	Inadequate	Inadequate	Unclear	Unclear	Adequate	Adequate	Unclear	Adequate	Adequate	Unclear
Harris et al. (2013)	RCT	University	Industry	Adequate	Unclear	Adequate	Adequate	Unclear	Unclear	Unclear	Adequate	Unclear	Adequate	Adequate	Unclear
Heydecke et al. (2005)	RCT	University	Grants	Adequate	Unclear	Adequate	Adequate	Unclear	Unclear	Unclear	Inadequate	Unclear	Adequate	Unclear	Unclear
Jofre et al. (2013)	RCT	University	Grants	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Unclear	Adequate	Unclear	Unclear
Karayazgan et al. 2017	CT	University	NR	NA	NA	Unclear	Unclear	Unclear	Unclear	Unclear	Adequate	Unclear	Adequate	Adequate	Unclear
Karbach et al. (2015)	RCT (crossover trial)	University	Industry	Unclear	Unclear	Inadequate	Inadequate	Unclear	Unclear	Adequate	Adequate	Unclear	Adequate	Inadequate	Unclear
Kleis et al. 2010	RCT	University	NR	Adequate	Unclear	Inadequate	Inadequate	Adequate	Adequate	Adequate	Adequate	Unclear	Inadequate	Unclear	Unclear
McKenna et al. (2018)	RCT	University, Geriatric Hospital	Public funding	Adequate	Unclear	Unclear	Unclear	Unclear	Unclear	Adequate	Adequate	Adequate	Adequate	Adequate	Unclear
Müller et al. (2013)	RCT	University	Industry	Adequate	Adequate	Unclear	Inadequate	Unclear	Unclear	Adequate	Adequate	Unclear	Adequate	Adequate	Unclear
Petricevic et al. (2012)	CT	University	Grants	NA	NA	Unclear	Unclear	Adequate	Adequate	Adequate	Adequate	Unclear	Adequate	Unclear	Unclear
Ribeiro et al. (2017)	CT	University	Public grant	NA	NA	Unclear	Unclear	Unclear	Unclear	Unclear	Adequate	Unclear	Adequate	Adequate	Unclear
Wolfart et al. (2005)	RCT	University	Public grant	Adequate	Unclear	Inadequate	Inadequate	Adequate	Adequate	Adequate	Adequate	Unclear	Adequate	Adequate	Unclear
Wolfart et al. (2014)	RCT	University	NR	Adequate	Adequate	Inadequate	Inadequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate

Abbreviations: CT, controlled trial; NA, not applicable; NR, not reported; RCT, randomized clinical trial.

3.4 | Synthesis of overall results: Outcomes on OHRQoL ($n = 43$ studies)

In total, 43 studies did not specifically report on the reasons for tooth loss of the included subjects (Awad et al., 2000; Allen et al., 2001; Fenlon et al., 2002; Jones et al., 2003; Heydecke et al., 2005; Wolfart et al., 2005, 2014; Allen et al., 2006; Ellis et al., 2007; Berretin-Felix et al., 2008; Kleis et al., 2010; Ha et al., 2012; Jabbour et al., 2012; Fillion et al., 2013; Harris et al., 2013; Veyrune et al., 2013; Awad et al., 2014; Cakir et al., 2014; Knipfer et al., 2014; Limmer et al., 2014; Karbach et al., 2015; Kurushima et al., 2015; Yamada et al., 2015; De Carvalho Dias et al., 2016; Ettl et al., 2016; Pozzi et al., 2016; Alfadda & Attard, 2017; El Osta et al., 2017; Enkling et al., 2017; Erkapers et al., 2017; Karayazgan-Saracoglu et al., 2017; Schuster et al., 2017; Marcello-Machado et al., 2018; Matthys et al., 2018; Yamamoto & Shiga, 2018; Fonteyne et al., 2019; Khan et al., 2019; Matthys, Vervaeke, Besseler, & De Bruyn, 2019; Matthys, Vervaeke, Besseler, Doornewaard, et al., 2019; Toia et al., 2019; Tôrres et al., 2019; Zembic et al., 2019; Boven et al., 2020).

3.4.1 | Partial edentulism ($n = 7$)

The impact of partial edentulism rehabilitation by means of different prosthetic modalities was assessed in seven studies with various study designs, employing different OHRQoL questionnaires, as well as measures of masticatory efficiency, symptoms, and patient satisfaction (Jones et al., 2003; Wolfart et al., 2005, 2014; Ha et al., 2012; Cakir et al., 2014; De Carvalho Dias et al., 2016; Khan et al., 2019).

Observational studies (n = 4)

One cross-sectional study (Jones et al., 2003) assessed the impact of tooth loss and the use of denture on OHRQoL and symptoms. Two prospective cohort studies (Ha et al., 2012; Khan et al., 2019) reported the positive effects of rehabilitation of partial edentulism with conventional partial dentures on OHRQoL and patient satisfaction. One case-series described an improvement of OHRQoL scores following a combined rehabilitation of mandibular partial edentulism and maxillary complete edentulism with the support of a partial denture and a complete denture, respectively (De Carvalho Dias et al., 2016).

Interventional studies (n = 3)

Three RCTs (Wolfart et al., 2005, 2014; Cakir et al., 2014) compared the impact of different partial edentulism rehabilitation modalities on OHRQoL and reported a significant improvement between before treatment and baseline.

3.4.2 | Complete edentulism of one arch ($n = 28$)

The impact of the rehabilitation of complete edentulism in one arch by means of different prosthetic modalities was assessed in 28 studies of various study designs, employing different OHRQoL questionnaires, as well as measures of masticatory efficiency, symptoms, patient satisfaction and complaints, and speech ability (Awad et al., 2000; Fenlon et al., 2002; Heydecke et al., 2005; Berretin-Felix et al., 2008; Kleis et al., 2010; Jabbour et al., 2012; Fillion et al., 2013; Harris et al., 2013; Veyrune et al., 2013; Awad et al., 2014; Knipfer et al., 2014; Karbach et al., 2015; Yamada et al., 2015; Ettl et al., 2016; Pozzi et al., 2016; Alfadda & Attard, 2017; Enkling et al., 2017; Erkapers et al., 2017; Karayazgan-Saracoglu et al., 2017; Schuster et al., 2017; Marcello-Machado et al., 2018; Matthys et al., 2018; Fonteyne et al., 2019; Matthys, Vervaeke, Besseler, & De Bruyn, 2019; Matthys, Vervaeke, Besseler, Doornewaard, et al., 2019; Toia et al., 2019; Zembic et al., 2019; Boven et al., 2020).

Observational studies (n = 21)

Four prospective cohort studies reported the effects of rehabilitation of complete edentulism in one arch on OHRQoL, patient satisfaction, and speech ability, showing an improvement following oral rehabilitation (Jabbour et al., 2012; Fillion et al., 2013; Alfadda & Attard, 2017; Fonteyne et al., 2019).

Seventeen case-series (Fenlon et al., 2002; Berretin-Felix et al., 2008; Veyrune et al., 2013; Knipfer et al., 2014; Yamada et al., 2015; Ettl et al., 2016; Pozzi et al., 2016; Enkling et al., 2017; Erkapers et al., 2017; Karayazgan-Saracoglu et al., 2017; Schuster et al., 2017; Marcello-Machado et al., 2018; Matthys et al., 2018; Matthys, Vervaeke, Besseler, & De Bruyn, 2019; Matthys, Vervaeke, Besseler, Doornewaard, et al., 2019; Toia et al., 2019; Zembic et al., 2019) reported on the impact of different single arch, maxillary or mandibular, rehabilitation modalities on OHRQoL, patient satisfaction and complaints, and masticatory efficiency. Overall, OHRQoL scores were reported to improve following oral rehabilitation.

Interventional studies (n = 7)

Six RCTs (Awad et al., 2000; Heydecke et al., 2005; Kleis et al., 2010; Harris et al., 2013; Karbach et al., 2015; Boven et al., 2020) compared the impact of different single-arch rehabilitation modalities on OHRQoL, social activities, patient satisfaction, and masticatory efficiency. The impact of oral rehabilitation evaluated by means of different questionnaires was reported to be positive in all the included studies.

One controlled trial reported higher OHRQoL improvement following implant-retained single-arch rehabilitation compared to conventional rehabilitation (Awad et al., 2014)

3.4.3 | Complete edentulism ($n = 8$)

The impact of the rehabilitation of complete edentulism of both arches through different modalities was assessed in eight studies of various study designs, employing different OHRQoL questionnaires, as well as measures of masticatory efficiency and patient satisfaction (Allen et al., 2001; Allen et al., 2006; Ellis et al., 2007; Limmer et al., 2014; Kurushima et al., 2015; El Osta et al., 2017; Yamamoto & Shiga, 2018; Tôrres et al., 2019).

Observational studies (n = 6)

Implant-supported dentures versus conventional dentures showed a greater enhancement in patients' QoL at 6-months' follow-up (El Osta et al., 2017). Reduced improvement was detected in completely edentulous subjects requesting implants in the mandible but rehabilitated with conventional dentures (Allen et al., 2001).

Four papers described the improvement in OHRQoL scores measured with GOHAI, OHIP-49, or OHIP-EDENT after rehabilitation of completely edentulous subjects with new, conventional dentures at different follow-up time points (Limmer et al., 2014; Kurushima et al., 2015; Yamamoto & Shiga, 2018; Tôrres et al., 2019). An improvement in OHRQoL scores and masticatory efficiency was found in three studies (Kurushima et al., 2015; Yamamoto & Shiga, 2018; Tôrres et al., 2019). One study reported a decline in OHIP-49 scores at 1 year (Limmer et al., 2014).

Interventional studies (n = 1)

In a population of subjects who received conventional dentures in the maxilla, and either a two-implant-retained or a conventional denture in the mandible, OHRQoL measured by OHIP-49 significantly improved after treatment in the absence of significant differences between groups (Allen et al., 2006). A controlled trial on different denture fabrication techniques (denture copy method vs. conventional) highlighted the lack of evidence on the superiority of either technique on OHRQoL improvement and patient satisfaction following rehabilitation (Ellis et al., 2007).

3.4.4 | Meta-analysis ($n = 12$)

Meta-analysis was performed for the severity of OHIP-14, OHIP-49, and GOHAI indices.

Meta-analysis of OHIP-14 included four articles (Cakir et al., 2014; Knipfer et al., 2014; De Carvalho Dias et al., 2016; Toia et al., 2019). The overall difference between baseline and post-treatment values was 10.52 (95% CI: [6.38; 14.66], $p < .01$, $I^2 = 98.09\%$) (Figure 3a).

Meta-analysis of OHIP-49 included two articles (Wolfart et al., 2014; Yamada et al., 2015). WMD between baseline and after treatment was 35.02 (95% CI: [24.07; 45.77], $p < .01$, $I^2 = 97.23\%$) (Figure 3b).

Meta-analysis of GOHAI comprised two articles (Shigli & Hebbal, 2010; Schuster et al., 2017). WMD between baseline and post treatment was 5.40 (95% CI: [0.22; 10.59], $p < .01$, $I^2 = 96.33\%$) (Figure 3c).

3.5 | Synthesis of the overall results: Systemic health-related outcomes ($n = 6$)

Systemic health-related outcomes were reported in six studies (Müller et al., 2013; Saarela et al., 2014, 2016; El Osta et al., 2017; Hoeksema et al., 2017; Shin et al., 2019).

3.5.1 | Cognitive impairment ($n = 2$)

Cognitive impairment was assessed in two studies (Saarela et al., 2016; Shin et al., 2019), retrieved by the use of CDR or MMSE. Cognitive impairment was significantly associated with non-rehabilitated lost teeth.

3.5.2 | Nutritional status ($n = 3$)

Nutritional status was evaluated with the MNA index in three studies (Müller et al., 2013; Saarela et al., 2014; El Osta et al., 2017). Untreated edentulism was associated with poor nutritional status. In all the studies, the performance of oral rehabilitation led to an improvement in MNA.

3.5.3 | Frailty ($n = 1$)

In one study (Hoeksema et al., 2017), community-living elderly with a higher number of remaining teeth and implant-supported overdentures were reported to be less frail, have better general health, use less medication, and exhibit better activity of daily living compared to edentulous subjects with conventional dentures.

3.5.4 | Systemic serum markers ($n = 1$)

Changes in serum markers (haemoglobin, albumin, folic acid, vitamin B12, and C-reactive protein) were assessed in a randomized clinical trial (Müller et al., 2013), where patients with implant-retained rehabilitation presented a decrease in C-reactive protein levels, although statistically insignificant. Other parameters did not show any trend through the study time points.

3.5.5 | Meta-analysis

No meta-analysis on systemic health data could be performed.

3.6 | Risk of bias in interventional studies

Risk of bias of individual studies is reported in Table 3. None of the included studies was judged at low risk of bias for all domains. Ten studies were judged at high risk (Heydecke et al., 2005; Wolfart et al., 2005, 2014; Allen et al., 2006; Ellis et al., 2007; Kleis et al., 2010; Müller et al., 2013; Awad et al., 2014; Cakir et al., 2014; Karbach et al., 2015) and eight were assigned a moderate risk of bias (Awad et al., 2000; Petricevic et al., 2012; Harris et al., 2013; Jofre et al., 2013; Karayazgan-Saracoglu et al., 2017; Ribeiro et al., 2017; McKenna et al., 2018; Boven et al., 2020).

3.7 | Quality evaluation of observational studies

None of the 12 cohort studies included earned the maximum of nine stars, which ranged from two to eight stars (Tables A1–A3). Two of the six included cross-sectional studies earned the maximum of seven stars for studies of such design (Saarela et al., 2014, 2016).

4 | DISCUSSION

The available evidence obtained through the present review suggests that oral rehabilitation of complete and partial edentulism appears to have a positive outcome in terms of OHRQoL, irrespective of the treatment modality. On the basis of these findings, it is not possible to ascertain the effect of oral rehabilitation in periodontitis stage IV patients, as literature exclusively related to such patients is absent. Therefore, in order to capture some evidence associated with the effect of rehabilitation on periodontitis patients, this review highlighted two groups of papers: those that included patients affected by periodontitis and those in which the population was not clearly specified. In both cases, OHRQoL showed important improvements. These improvements were of similar magnitude and to an extent that it is considered relevant for the patient. Moreover, emerging evidence indicates a potential improvement in systemic health following oral rehabilitation, although the effects on systemic parameters remain unclear and require further research.

Periodontitis stage IV is a severe condition characterized by the loss of at least four teeth or a degree of complexity that would impair masticatory function (Papapanou et al., 2018). Periodontitis, especially in its severe forms, has been recognized to negatively affect OHRQoL (Needleman et al., 2004; Graziani & Tsakos, 2020). No paper that exclusively included periodontal patients was found, and therefore we specifically examined the articles (13 out of 59 papers) in which some patients affected by periodontitis were included. However, it should be borne in mind that, despite attempts to directly contact the authors, it has not been possible to evaluate whether periodontitis was the cause of tooth loss. Thus, even the included periodontitis cases might have had tooth loss due to reasons other than periodontitis. Therefore, we cannot exclude that in these papers other stages of periodontitis might have been presented. Overall, the available data for this group of studies and from the dedicated meta-analysis on OHIP-49 severity indicate unanimously that OHRQoL improves significantly following oral rehabilitation to an extent that is considered highly relevant for the patient (Tsakos et al., 2012).

The analysis of the remaining papers confirmed the effect of OHRQoL on all psychometric testing. OHIP-49 showed an improvement of the same entity of the papers including periodontitis cases. Overall, these findings are indirectly in agreement with previous data on tooth loss. In general, a higher number of remaining teeth appears to be associated with higher self-reported OHRQoL scores (Jones et al., 2003; Gerritsen et al., 2010; Ferreira et al., 2019). In patients with a lower number of remaining teeth, wearing a denture appears as a critical factor in reducing pain, distress, and discomfort for patients. Oral rehabilitation, whether with dentures or bridges, led to an improvement in QoL, while the effects on masticatory efficiency were less clear.

In general, a high level of heterogeneity was found across the studies. In particular, the different types of populations, study design, rehabilitations, and follow-up may account for the heterogeneity of the included studies. Conversely, the types of edentulism (partial vs. full), the involvement of one or both arches, and the prosthodontic treatment modality employed did not seem to influence the outcome of the rehabilitation as assessed through different methods of psychometric testing. This finding is consistent with previous literature (Emami et al., 2009; Reissmann et al., 2017; Kutkut et al., 2018; Yao et al., 2018; Ali et al., 2019). While previous reviews focused exclusively on the comparison between different modalities of oral rehabilitation, and their impact on OHRQoL and/or were limited to specific study designs, in the present review studies with different design and rehabilitation modalities were included.

Subjects with partial edentulism appeared to benefit both from dentures and bridges. However, the limited number of studies reporting on oral rehabilitation of partial edentulism hinders the drawing of firm conclusions regarding the type of rehabilitation associated with a more significant improvement in OHRQoL. Although it might appear that implant-supported prostheses contribute to a greater improvement in OHRQoL when compared to dentures and tooth-supported bridges (Pavel et al., 2012), patients' expectations have been reported to play a major role in OHRQoL (Allen et al. 2003). As reported by Allen et al. (2003), receiving the treatment of choice seems to lead to a higher improvement in OHRQoL scores, irrespective of the type of denture provided. Conversely, subjects who initially requested implants, but were eventually treated through conventional dentures, reported the lowest improvement both in terms of QoL and denture satisfaction. From this perspective, patient expectations may constitute a source of bias in the evaluation of the efficacy and effectiveness of the rehabilitation.

An overall improvement in OHRQoL was also reported for both bridges and dentures in patients with one or both fully edentulous dental arches. Several studies investigated the OHRQoL outcomes following rehabilitation with conventional dentures and implant-retained overdentures, with the use of implant-retained overdentures appearing to be associated with a higher degree of improvement compared to conventional complete dentures (Heydecke et al., 2005; El Osta et al., 2017). However, the superiority of implant-retained overdentures versus conventional rehabilitation is still debated (Emami et al., 2009; Kutkut et al., 2018; Yao et al., 2018). A greater enhancement in QoL and nutritional status is surprisingly rarely described for implant-supported prostheses compared to conventional dentures (Saarela et al., 2016).

Among the studies included in this systematic review, only a few reported the impact of oral rehabilitations on systemic outcomes. Cognitive impairment and nutritional status were the most frequently assessed parameters. In particular, cognitive impairment appears more severe in edentulous patients in the absence of oral rehabilitation (Saarela et al., 2016; Shin et al., 2019). Thus, it is not possible to

speculate that rehabilitation of missing teeth may have a role in the improvement of the cognitive status, which is due to confounding factors and limited study numbers. However, a direct relationship between cognitive impairment and the number of missing teeth remains controversial (Naorungroj et al., 2013; Nilsson et al., 2014). Moreover, the absence of edentulism rehabilitation was reported to be related to poorer nutritional status (Saarela et al., 2014, 2016). This may be related to the impact of oral rehabilitation on the masticatory efficiency (De Carvalho Dias et al., 2016; Ribeiro et al., 2017; Yamamoto & Shiga, 2018; Tôrres et al., 2019), which seems to improve in particular following implant-retained rehabilitation (Marcello-Machado et al., 2018). However, nutritional status is complex and may not be only determined by the dental status. This fact is corroborated by the study of Müller et al., where no differences were found in terms of nutritional status and systemic markers following oral rehabilitation (Müller et al., 2013). The number of missing teeth and the presence of prosthodontic appliances may also be related to frailty (Hoeksema et al., 2017), defined as a clinical syndrome involving mutually exacerbating cycles of negative energy balance, sarcopaenia, and diminished strength and tolerance to exertion (Xue, 2011). This connection may also be indirectly impacted through a mosaic of other factors, some of them already mentioned, as it is also reported in the literature that frail individuals have impaired masticatory function (Watanabe et al., 2017).

The reader should be aware of the intrinsic limitations of the included literature. The focused question of the review aimed to establish whether oral rehabilitation in patients affected by periodontitis improved their OHRQoL. The reasons for edentulism were often not clearly specified. Although according to our investigation some studies involved patients affected by periodontitis, it was not possible to collect sufficient information on the reasons for tooth loss for all the included studies. All the studies were considered at high or moderate risk of bias, which accounts for an intrinsic difficulty in the actual reliability of the analysis. In particular, the therapist's experience was seldom reported. Moreover, examiner blinding was generally absent also due to the study design. Furthermore, completeness of data and missing data reporting were judged unclear in a large percentage of the studies. Several studies reported only qualitative evaluation, thus hindering the generalizability and applicability of the results. In particular, the extreme variability between the types of the oral rehabilitations, the heterogeneity of data adjustment provided by the studies included, and the different evaluation of oral and systemic outcomes may have had an impact. Similarly, lack of information regarding the number of missing teeth prior to rehabilitation led to the exclusion of some studies from the review. Furthermore, it was not possible to investigate the effects of bridges or dentures versus no treatment, as none of the included studies reported the comparison of a defined oral rehabilitation modality versus no treatment. Importantly, the quality of the included studies was often heterogeneous. Although the quality of RCTs was often adequate, the inclusion of studies with different designs frequently compromised the overall study quality, which became "insufficient".

5 | CONCLUSION

In the absence of a specific analysis performed on a population of patients with stage IV periodontitis, the available data suggest and support the rationale for providing rehabilitation of missing teeth, and as such should be recognized as an important factor in improving patient health and well-being. Further investigations on the effect of oral rehabilitation in stage IV periodontitis patients is advocated.

ACKNOWLEDGEMENTS

The study was self-supported by the Chair of Periodontology of the University of Pisa.

CONFLICT OF INTEREST

The authors declared no conflicts of interest in connection with this article.

ETHICS STATEMENT

There were no external sources of funding to support the conduct of this review. The local ethical committee does not require ethical approval for systematic reviews.

AUTHOR CONTRIBUTIONS

Stefano Gennai, Rossana Izzetti, Maria C. Pioli, Larisa Music, and Filippo Graziani contributed to the conception and design, data acquisition, data analysis and interpretation, and writing and revision of the manuscript. Rossana Izzetti, Maria C. Pioli, and Larisa Music contributed to data acquisition. Stefano Gennai contributed to data analysis. Stefano Gennai, Rossana Izzetti, and Filippo Graziani contributed to data interpretation and writing and revision of the manuscript. All authors reviewed and approved the final version of the manuscript and agreed to be accountable for all aspects of work ensuring integrity and accuracy.

DATA AVAILABILITY STATEMENT

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

ORCID

Stefano Gennai https://orcid.org/0000-0002-1554-9966
Rossana Izzetti https://orcid.org/0000-0003-4902-7813
Larisa Music https://orcid.org/0000-0002-2946-2124
Filippo Graziani https://orcid.org/0000-0001-8780-7306

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How to cite this article: Gennai, S., Izzetti, R., Pioli, M. C., Music, L., & Graziani, F. (2022). Impact of rehabilitation versus edentulism on systemic health and quality of life in patients affected by periodontitis: A systematic review and meta-analysis. *Journal of Clinical Periodontology*, *49*(Suppl. 24), 328–358. https://doi.org/10.1111/jcpe.13526

APPENDIX

TABLE A1 Summary of risk of bias in cohort studies

Author, year	Representativeness of the exposed cohort (max 1 star)	Selection of non-exposed cohort (max 1 star)	Ascertainment of exposure (max 1 star)	Demonstration that outcome was not present at start of study (max 1 star)	Comparability of cohorts on the basis of the design or analysis (max 2 stars), Study controls for age (= most important factor), Study controls for smoking (=additional important factor)	Assessment of outcome (max 1 star), Independent or blind assessment stated in the paper, or confirmation of the outcome by reference to secure records (x-rays, medical/dental records, etc.), Record linkage, Self-report only (no confirmation by secure records), No description	Was follow-up long enough for outcomes to occur (max 1 star)	Adequacy of follow-up of cohorts (ensuring losses are not related to exposure or outcome) (max 1 star)	Total
Higuchi et al. (2020)	0	0	1	1	1	1	1	1	6
Fonteyne et al. (2019)	0	0	1	1	1	1	0	0	4
Khan et al. (2019)	0	0	1	1	0	0	1	1	4
Alfadda et al. 2017	1	0	1	1	0	0	1	1	5
El Osta et al. (2017)	0	0	1	1	1	0	1	1	5
Kurushima et al. (2015)	0	0	1	1	0	0	0	0	2
Fillion et al. (2013)	1	0	1	1	2	1	1	1	8
Ha et al. (2012)	0	0	1	1	1	0	1	1	5
Jabbour et al. (2012)	0	0	1	1	0	0	1	1	4
Allen et al. 2003	1	1	1	1	1	0	0	0	5
Allen et al. (2001)	0	0	1	1	1	0	1	1	5

TABLE A2 Summary of risk of bias in cross-sectional studies

Author, year	Representativeness of the exposed subjects (max 1 star)	Selection of non-exposed subjects (max 1 star)	Ascertainment of exposure (max 1 star)	Ascertainment of outcome (max 1 star)	Comparability of exposed and non-exposed groups on the basis of the design or analysis (max 2 stars)	Assessment of outcome (max 1 star)	Total
Shin et al. (2019)	1	1	1	1	1	1	6
Hoeksema et al. (2017)	0	0	1	1	1	1	4
Saarela et al. (2014)	1	1	1	1	2	1	7
Saarela et al. (2014)	1	1	1	1	2	1	7
Jones et al. (2003)	0	0	1	1	1	1	4

TABLE A3 Summary of risk of bias in case–control studies

Author, year	Representativeness of the exposed subjects (max 1 star)	Selection of non-exposed subjects (max 1 star)	Ascertainment of exposure (max 1 star)	Ascertainment of outcome (max 1 star)	Comparability of exposed and non-exposed groups on the basis of the design or analysis (max 2 stars)	Assessment of outcome (max 1 star)	Total
Ribeiro et al. (2017)	1	1	1	1	1	1	5