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SUPPLEMENT ARTICLE

WILEY CLINICAL ORAL IMPLANTS RESEARCH

Implant-supported cantilevered fixed dental rehabilitations in fully edentulous patients: Systematic review of the literature. Part II

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Abstract

Aim: To investigate fully edentulous patients rehabilitated with cantilever-fixed implant-supported restorations and to analyse which complications are reported for this type of treatment.

Materials and Methods: Two operators screened the literature (MEDLINE, EMBASE) and performed a hand search on the main journals dealing with implantology and prosthetics until 31 December 2017. Only articles that considered cantilever implant-fixed restorations with at least 10 patients and with a mean follow-up of at least 5 years were selected. The outcome variables were survival of implants and prosthesis, mechanical, technical and biological complications, marginal bone loss. The review was performed according to the PRISMA statements. The risk of bias was evaluated for each article. Failure and complication rates were analysed using random effect Poisson regression models to obtain summary estimate of 5- and 10-year survival and complication rates.

Results: Fourteen papers for fully edentulous patients were selected. The estimated 5 to 10 years survival rate was calculated to be 99.00% and 96.7% for the implants and the prosthesis, respectively. A total of 299 complications (technical and biological) were reported with a cumulative 5–10 years complication rate of 44.41% and 39.46% for the patients and for the prosthesis, respectively.

Conclusions: There is evidence that cantilever can be successful treatment in fully edentulous patients.

1 | INTRODUCTION

The first use of dental implant was documented in restorations of fully edentulous patients. These reconstructions were provided in both jaws and consisted in 4–6 implants supporting a complete fixed prosthesis. Implants were often placed only in intra-foramina area or in the anterior maxilla. The restorations were then mainly delivered with bilateral cantilevers (Adell, Hansson, Brånemark, & Breine, 1970; Brånemark et al., 1969).

The use of implant-supported restorations with cantilevers has been documented over time. Studies have analysed this type of restoration and assessing the survival rate of restorations and implants as well as the rate and type of complications.

The rational of the use of cantilevers in fully edentulous patients is the possibility of providing full-arch reconstructions by placing implants in more anterior areas, thus avoiding resorbed or low quality bone regions. More evidence has been published (Heydecke, et al., 2012) reporting that the use of only four or six implants could be sufficient to support a full-arch restoration: whether the last implant should be placed underneath the last tooth or not is still in debate. The positioning of an implant in posterior areas may often require more complex procedure, such as bone augmentations procedures,

tilted implants or use implants with reduced dimensions. Other systematic reviews reported that major reconstructions can be effective but can exhibit major complications and need to be carefully applied in cases with ideal conditions (Chiapasco, Zaniboni, & Boisco, 2006; Esposito, Grusovin, Worthington, & Coulthard, 2006).

Cantilevered implant-supported rehabilitations can be a prosthetic alternative. The presence of the cantilever may produce a bio-mechanical risk, that could lead to implant and/or prosthetic failure. In vitro studies have revealed that higher stress to the implant closest to the cantilever extension may be concentrated at the marginal bone level and may pose a risk to marginal bone loss. (Sertgoz & Guvener, 1996; Stegaroiu, Sato, Kusakari, & Miyakawa, 1998; Zampelis, Rangert, & Heijl, 2007). By contrast, in humans the results of higher stresses on implants remain unclear.

Few systematic reviews have been published with main focus on restorations with cantilever (Aglietta et al., 2009; Romeo & Storelli, 2012; Zurdo, Romão, & Wennström, 2009). None of them considered the outcome of cantilevered prostheses used in full-arch fixed reconstructions.

The main objective of this systematic review was to assess the survival and complication rate of in full-arch implant cantilever-fixed dental prosthesis (FAICFDP) in different clinical situations.

2 | MATERIAL AND METHODS

The present systematic review was designed to report data on full-arch and partial-fixed reconstructions with cantilever. During the discussion of the consensus, the authors decided to divide the results in two, one considering full-arch reconstructions and the other considering partial reconstructions. Results concerning full-arch reconstructions are reported here while results about partial reconstructions are reported in another paper (Storelli, Scanferla, Palandrani, Mosca, & Romeo, 2017). Therefore, material and methods were previously reported in another paper (Storelli et al., 2017) and are only briefly reported here. The present review is reported according to the PRISMA (Preferred Reporting Items Systematic review and Meta-Analyses) statement (Liberati et al., 2009; Moher, Liberati, Tetzlaff, & Altman, 2009). The focus of the present review was to determine the survival rate of implants and prosthesis in fully edentulous patients treated with cantilevered implant-supported restorations.

2.1 | Types of participants

Patients who received full-arch cantilevered implant-supported rehabilitations.

2.2 | Types of interventions

Any rehabilitations that was produced with cantilevered teeth. Only full-arch cantilevered restorations on implants were considered in the present review.

2.3 | Types of outcome measures

Several variables were considered for analysis:

1. Implant survival rate
2. Prosthetic survival rate
3. Biological complications
4. Prosthetic complications (Mechanical and Technical)
5. Marginal bone loss

Other variables were searched and described when present: loading time of the rehabilitations, reconstruction material, implant system used.

2.4 | Types of studies

The present systematic review considered both prospective and retrospective studies, randomized and controlled clinical trials as well as cohort studies and case series. Studies had to report data on minimum 10 participants and have a minimum of 5-year follow-up.

2.5 | Search strategy

The English literature was searched as reported in Part I (Storelli et al., 2017). The aim of the present review was to screen the literature for papers reporting at least a mean of 5-year follow-up data on cantilevered rehabilitations in fully edentulous patients.

2.6 | Inclusion and exclusion criteria

Detailed exclusion and inclusion criteria are reported in part I (Storelli et al., 2017). Both retrospective and prospective studies were selected with a mean follow-up of a minimum of 5 years and at least 10 rehabilitations. Studies from which data on selected outcome variables could not at all be retrieved or calculated were not considered.

2.7 | Study selection and data extraction

Full text was obtained either for articles meeting the inclusion criteria or for those whose abstract presented unclear data. Two authors

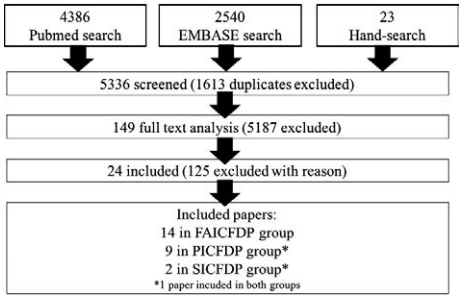

FIGURE 1 Flow Chart

TABLE 1 Excluded studies

Cantilever data not retrievable	Koller, Pereira-Cenci, and Boscato (2016); Ozgur, Kazancioglu, Demirtas, Deger, and Ak (2016); Mangano et al. (2014); Ekfeldt, Zellmer, and Carlsson (2013); Degidi, Nardi, and Piattelli (2013); Wittneben et al. (2014); Heschl et al. (2012); Ortorp and Jemt (2012); Malo, de Araújo Nobre, Lopes, Moss, and Molina (2011); Krennmair, Seemann, Schmidinger, Ewers, and Piehslinger (2010); Eliasson et al. (2010); Davó (2009); Isaksson, Becktor, Brown, Laurizohn, and Isaksson (2009); Degidi, Iezzi, Perrotti, and Piattelli (2009); Ortorp and Jemt (2009); Gualini, Gualini, Cominelli, and Lekholm (2009); Blanes, Bernard, Blanes, and Belser (2007); Rasmusson, Roos, and Bystedt (2005); Hartman and Cochran (2004); Åstrand et al. (2004); Attard and Zarb (2004); Ekelund, Lindquist, Carlsson, and Jemt (2003); Murphy, Absi, Gregory, and Williams (2002); Raghoebar, Timmenga, Reintsema, Stegenga, and Vissink (2001); Tinsley, Watson, and Russell (2001); Brägger, Aeschlimann, Bürgin, Hämmerle, and Lang (2001); Friberg, Gröndahl, Lekholm, and Brånemark (2000); Becker and Kaiser (2000); Schwartz-Arad, Gulayev, and Chaushu (2000); Arvidson, Bystedt, Frykholm, von Konow, and Lothigius (1998); Schwartz-Arad and Chaushu (1998); Keller, Tolman and Eckert (1998); Parein, Eckert, Wollan, and Keller (1997); Schnitman, Wöhrle, Rubenstein, DaSilva, and Wang (1997); Jemt and Lekholm (1995); Brånemark, Svensson, and van Steenberghe (1995); Hemmings, Schmitt, and Zarb (1994); Naert, Quirynen, van Steenberghe, and Darius (1992); Zarb and Schmitt (1991)
Non-human study	Costa, Santos, Nary, and Brånemark (2015); Kupeyan and Clayton (2004); McAlarney and Stavropoulos (2000)
Mean follow-up <5 years	Correia, Gouveia, Felino, Costa, and Almeida (2017); Wang, Judge, and Bailey (2016); Tartaglia, Maiorana, Gallo, Codari, and Sforza (2016); Francetti, Rodolfi, et al. (2015); Mundt, Heinemann, Schwahn, and Biffar (2012); Lee et al. (2011); Francetti, Romeo, Corbella, Taschieri, and Del Fabbro (2012); Mangano et al. (2011); Lai et al. (2008); Nedir, Bischof, Szmukler-Moncler, Belser, and Samson (2006); Ibañez et al. (2005); Balshi, Wolfinger, and Balshi (2005); Becker (2004); Romeo et al. (2003); Engstrand et al. (2003); Ahrén and Kahnberg (2001); Brocard et al. (2000); Eliasson, Palmqvist, Svenson, and Sondell (2000); Haas, Mendorff-Pouilly, Mailath, and Bernhart (1998); Kucey (1997); Gotfredsen (1997); Carlson and Carlsson (1994)
Number of patients <10	Deporter, Ogiso, Sohn, Ruljancich, and Pharoah (2008); Van Nimwegen, Raghoebar, Tymstra, Vissink, and Meijer (2017); Fischer and Stenberg (2013)
On natural teeth	Lam, Botelho, and McGrath (2013); Cordaro, Ercoli, Rossini, Torsello, and Feng (2005)
Out of topic (no cantilever)	Agliardi, Romeo, Panigatti, de Araújo Nobre, and Maló (2017); Malo, de Araujo Nobre, Guedes, and Almeida (2017); Niedermaier et al. (2017); Zanolla et al. (2016); Lee, Kweon, Choi, and Kim (2016); Esposito et al. (2016); Cavalli et al. (2016); Zhang, Shi, Gu, and Lai (2016); Imburgia and Del Fabbro (2015); Ata-Ali et al. (2015); Tealdo et al. (2014); Pettersson and Sennerby (2015); Ravald, Dahlgren, Teiwik, and Gröndahl (2013); Kim et al. (2013); Al-Nawas et al. (2012); Ozkan, Akoğlu, and Kulak-Ozkan (2011); Browaeys et al. (2011); Lethaus, Kälber, Petrin, Brandstätter, and Weingart (2011); Mura (2012); Schrott, Jimenez, Hwang, Fiorellini, and Weber (2009); Botticelli, Renzi, Lindhe, and Berglundh (2008); Friberg, Raghoebar, Grunert, Hobkirk, and Tepper (2008); Åstrand, Ahlqvist, Gunne, and Nilson (2008); Glauser, Zembic, Ruhstaller, and Windisch (2007); Jaffin, Kolesar, Kumar, Ishikawa, and Fiorellini (2007); Romeo, Ghisolfi, Rozza, Chiapasco, and Lops (2006); Romeo, Lops, et al. (2006); Sullivan, Vincenzi, and Feldman (2005); Quirynen et al. (2005); Degidi and Piattelli (2005); Vigolo, Givani, Majzoub, and Cordioli (2004); Zinsli, Sägesser, and Mericske (2004); Lambrecht, Filippi, Künzel, and Schiel (2003); Davis, Packer, and Watson (2003); Weng et al. (2003); Attard and Zarb (2003); Brosky, Korioth, and Hodges (2003); Naert et al. (2002); Fortin, Sullivan, and Rangert (2002); Wyatt and Zarb (2002); Attard and Zarb (2002); Zarb and Zarb (2002); Ferrigno, Laureti, Fanali, and Grippaudo (2002); Sullivan, Sherwood, and Porter (2001); Ekfeldt et al. (2001); Hellem et al. (2001); Merickse-Stern, Aerni, Geering, and Buser (2001); Allen, McMillan, and Walshaw (2001); Vajdovich and Fazekas (1999); Noack, Willer, and Hoffmann (1999); Schliephake, Schmelzeisen, Husstedt, and Schmidt-Wondera (1999); Chaushu and Schwartz-Arad (1999); Makkonen et al. (1997); Zarb and Schmitt (1993)
Same pool of patients of other article	Cavalli, Corbella, Taschieri, and Francetti (2015); Fischer, Stenberg, Hedin, and Sennerby (2008)

assessed the full texts (SS and GP). Any disagreement was resolved by discussion with the other reviewers (ER and MDF). Survival rate of implant and prosthesis were extracted or calculated from the original articles. Implant survival was considered if the implant was present at the follow-up examination; prosthesis survival was considered if the restoration was present at the follow-up visit without any modifications. Biological and Prosthesis complications were considered. Moreover, when reported, data on marginal bone loss were also extracted.

When the reported data were unclear, authors contacted by emails the corresponding authors and asked for more information.

2.8 | Risk of bias assessment

The risk of bias assessment criteria were previously reported (Storelli et al., 2017).

After judgement was given for each of the above-mentioned domains, studies were grouped into the following categories:

1. Low risk of bias (plausible bias unlikely to seriously alter the results) if all criteria were met
2. Moderate risk of bias (plausible bias that raises some doubt about the results) if one or more criteria were partly met or were assessed as unclear

TABLE 2 Study and patient characteristics of the included studies (full-arch prostheses)

Study	Implant system	Study design	Mean Follow-up, yrs	No. implants placed (ICFDPs/patients)
Cid et al. (2014)	Connexao Sistemas de Protese and Neodent	Prospective	5	110 (42/42)
Crespi et al. (2014)	Sweden & Martina	Prospective	8	272 (34/28)
Romanos et al. (2014)	Ankilos	Prospective	6.5	203 (31/27)
Fischer and Stenberg (2013)	Straumann Dental Implant System®	Prospective	10	139 (24/24)
Mertens and Steveling (2011)	Astra Tech® Dental Implant System	Prospective	8.34	106 (17/17)
Gallucci et al. (2009)	Straumann Dental Implant System®	Prospective	5	237 (45/45)
Hellem et al. (2001)	Straumann Dental Implant System®	Prospective	5	144 (28/28)
Malo et al. (2016)	Brånemark System®	Retrospective	5.6	63 (41/36)
Purcell et al. (2015)	Brånemark System®	Retrospective	8.5	118 (23/23)
Maló et al. (2015)	Brånemark System®	Retrospective	6.4	660 (147/104)
Francetti et al. (2015)	Brånemark System®	Retrospective	5	380 (95/86)
Krennmair et al. (2013)	Camlog	Retrospective	5.5	168 (42/42)
Purcell et al. (2008)	Brånemark System®	Retrospective	7.9	233 (46/46)
Rosén and Gynther (2007)	Brånemark System®	Retrospective	10	103 (19/19)

Note. ICFDPs: implant-supported, cantilever-fixed dental prostheses; NR: not reported.

TABLE 3 Implant and prosthesis characteristics of the included studies (full-arch prostheses)

Study	No. implants available for analysis (ICFDPs/patients)	Implant system	Surface	Implant diameter (mm)	Implant lenght (mm)
Malo et al. (2016)	57 (38/33)	Brånemark System®	Rough	4	13–15
Purcell et al. (2015)	118 (23/23)	Brånemark System®	Rough	3.25–4.5	8–18
Cid et al. (2014)	110 (42/42)	Connexao Sistemas de Protese and Neodent	Rough	NR	NR
Crespi et al. (2014)	272 (34/28)	Sweden & Martina	Rough	3.5–4.2–5	10–13
Maló et al. (2015)	655 (147/104)	Brånemark System®	Rough	NR	NR
Romanos et al. (2014)	203 (31/27)	Ankylos	NR	3.5–4.5– 5.5	8–9.5–11–14
Francetti, Corbella, et al. (2015)	380 (95/86)	Brånemark System®	Rough	4	NR
Krennmair et al.(2013)	152 (38/38)	Camlog	NR	3.8– 4.3	11–13–16
Fischer and Stenberg (2013)	132 (23/23)	Straumann Dental Implant System®	Rough	4.1	8–12
Mertens and Steveling (2011)	99 (16/16)	Astra Tech® Dental Implant System	Rough	3,5–4	9–15
Gallucci et al. (2009)	237 (45/45)	Straumann Dental Implant System®	Rough	NR	8–10–12–14–16
Purcell et al. (2008)	233 (46/46)	Brånemark System®	Rough	2.25–4.5	8–18
Rosén and Gynther (2007)	100 (19/19)	Brånemark System®	Smooth	NR	NR
Hellem et al. (2001)	140 (28/28)	Straumann Dental Implant System®	Rough	4.1	8–16

Note. NR: not reported.

No. implants available for analysis (ICFDPs/ patients)	Age range (mean), years	Setting	Type of extension	Location of reconstruction
110 (42/42)	43–87 (NR)	University	Bilateral cantilever	22 maxilla, 20 mandible
272 (34/28)	46–77 (59.3)	Hospital	Bilateral cantilever	24 maxilla, 10 mandible
203 (31/27)	NR (59.1)	NR	Bilateral cantilever	Maxilla and mandible
132 (23/23)	NR (64)	Hospital	Bilateral cantilever	Maxilla
99 (16/16)	41–69 (55.6)	University	Mixed	Maxilla
237 (45/45)	34–78 (59.5)	University	Bilateral cantilever	Mandible
140 (28/28)	40–70 (57.7)	NR	Bilateral cantilever	Mandible
57 (38/33)	32–78 (55)	Private clinic	Bilateral 49 (initial)- 43 (final) monolateral 14	Maxilla and mandible
118 (23/23)	44–71 (58)	NR	Bilateral cantilever	Mandible
655 (147/104)	NR (55.5)	Private clinic	Bilateral 119 monolateral 28	Maxilla and mandible
380 (95/86)	41–85 (58.4)	Hospital	Bilateral cantilever	34 maxilla 61 mandible
152 (38/38)	NR (67.1)	NR	Bilateral cantilever	Mandible
233 (46/46)	NR (59)	NR	Bilateral cantilever	Mandible
100 (19/19)	NR (60.4)	NR	Bilateral cantilever	Maxilla

Loading	Type of extension	Location of reconstruction	Fixation	Type of material
Immediate <7 days	Bilateral- monolateral	Maxilla and mandible	Screw-retained	Metal-resin, Metal-ceramic, Ceramic
Conventional >3 months	Bilateral cantilever	Mandible	Screw-retained	Metal-resin
Conventional >3 months	Bilateral cantilever	22 maxilla, 20 mandible	Screw-retained	NR
Immediate <7 days	Bilateral cantilever	24 maxilla, 10 mandible	Cemented and screw-retained	Metal-ceramic
Immediate <7 days	Bilateral -monolateral	Maxilla and mandible	Screw-retained	Metal-resin,Metal-ceramic, Resin
Immediate <7 days	Bilateral cantilever	Maxilla and mandible	Cemented	Metal-ceramic
Immediate <7 days	Bilateral cantilever	34 maxilla 61 mandible	Screw-retained	Metal-resin
Early 1-3 months	Bilateral cantilever	Mandible	Screw-retained	Metal-resin
Early and conventional	Bilateral cantilever	Maxilla	Screw-retained	Metal-resin
Conventional >3 months	Mixed	Maxilla	Screw-retained	Metal-resin
Conventional >3 months	Bilateral cantilever	Mandible	Screw-retained	Metal-resin/ Metal-ceramic
NR	Bilateral cantilever	Mandible	Screw-retained	Metal-resin
NR	Bilateral cantilever	Maxilla	Screw-retained	Metal-resin
Conventional >3 months	Bilateral cantilever	Mandible	Screw-retained	Gold resin

TABLE 4 Risk of bias summary (full-arch prostheses)

	Blinding of outcome assessment	Comparability of control and treatment groups at entry	Clear definition of inclusion and exclusion criteria	Outcome measurement method description	Completeness of the outcome data reported	Recall rate	Sample size	Number of surgeon involved
Crespi et al. (2014)	?	+	+	?	?	+	–	+
Fischer and Stenberg (2011)	–	+	+	+	+	+	–	+
Maló et al. (2015)	?	–	+	+	+	+	+	?
Cid et al. (2014)	–	+	+	?	?	+	+	?
Malo et al. (2016)			+	+	+	?	+	?
Purcell et al. (2015)			–	+	+	–	–	–
Romanos et al. (2014)			–	?	+	?	–	?
Francetti et al. (2015)			+	+	+	?	+	?
Krennmair et al. (2013)			?	+	+	?	+	?
Rosén and Gynther (2007)			+	+	+	–	–	+
Purcell et al. (2008)			–	+	+	?	+	?
Mertens and Steveling (2011)			+	+	+	+	–	+
Gallucci et al. (2009)			?	+	+	+	+	?
Hellem et al. (2001)			–	?	+	+	+	?

Note. +, Low risk of bias; –, High risk of bias; ?, Moderate risk of bias.

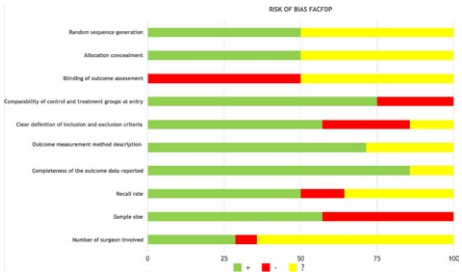

FIGURE 2 Risk of bias graph

3. High risk of bias (plausible bias that seriously weakens confidence in the results) if one or more criteria were not met.

2.9 | Statistical analysis

Failure and complication rates were calculated by dividing the number of events (failures or complications) in the numerator by the total exposure time (implant, patient or prosthesis-time) in the denominator, similar to previous systematic reviews (Romeo & Storelli, 2012). Failures and complications were directly extracted from the publications, as well as the mean follow-up time. Exposure time was calculated by multiplying the mean follow-up time by the number of implants or ICFDPs available. The mean follow-up duration was directly extracted by the articles, provided by adjunctive information by the authors or estimated from the original data. For further analysis, the total number of events was considered to be Poisson distributed for a given sum of implant exposure years, and Poisson regression with a logarithmic link function and total exposure time per study as an offset variable was used (Kirkwood & Sterne, 2003). Event rates for implants and prostheses were calculated by dividing the total number of events by the respective total exposure time in years.

Robust standard errors were calculated to obtain 95% confidence intervals of the summary estimates of the event rates. To assess heterogeneity of the study-specific event rates, the Spearman goodness-of-fit statistics and associated *p*-value were calculated. If the goodness-of-fit *p*-value was below 0.05, indicating heterogeneity, random effects Poisson regression (with Gamma-distributed random effects) was used to obtain a summary estimate of the event rates. Five- and 10-year survival and complication proportions were estimated through the relationship between event rate and survival function S, $S(T)=\exp(-T \times \text{event rate})$, assuming constant event rates (Kirkwood & Sterne, 2003). Ninety-five per cent confidence intervals (CIs) of the summary estimates of the event rates obtained from the Poisson regression were reported. The 95% CIs for survival probabilities were obtained using the 95% confidence limits from the summary event rates. All analyses were performed using IBM SPSS Statistics version 24 (IBM Corporation, Armonk, NY).

3 | RESULTS

The electronic search identified a total of 6926 titles (4386 MEDLINE, 2540 EMBASE). Another 23 titles were included after manual search. After de-duplication a total of 5336 studies were screened. A total of 149 papers underwent full- text analysis (Figure 1). After full text reading, 125 papers were excluded. Reasons for excluding papers were mainly follow-up less than 5 years, papers on natural teeth, in vitro or non-clinical studies. Also, papers non-clearly reporting data on cantilever were excluded. When, after discussion, there was still a doubt, authors were contacted by email and asked for better explanations. Reason for exclusion can be found in Table 1. Any disagreement was resolved by discussion. Finally, 24 papers were included: 10 papers were selected for the partially edentulous and 14 for the fully edentulous cantilevered restorations. In the present review only those concerning fully edentulous cantilevered restorations were considered (Table 2).

3.1 | Excluded studies

The main reason for exclusion of the full text is reported in Table 1. Out of 125 excluded papers, 54 examined prostheses without cantilevers, 39 did not report data about cantilever, 22 had a follow-up less than 5 years, 3 were non-human studies, 3 had number of patients less than 10.2 were about rehabilitations on natural teeth, 2 had the same pool of patients as other articles with longer follow-up already included in the study. Additional 10 studies were not considered in the present review because they were included in part I (Storelli et al., 2017).

3.2 | Study characteristics

Fourteen studies about full-arch restorations were included (Cid, Stanley, Cordero, Benfatti, & Bianchini, 2014; Crespi, Capparè, Gastaldi, & Gherlone, 2014; Fischer & Stenberg, 2011; Francetti, Corbella, Taschieri, Cavalli, & Del Fabbro, 2015; Gallucci, Doughtie, Hwang, Fiorellini, & Weber, 2009; Hellem et al., 2001; Krennmair, Seemann, Weinländer, Krennmair, & Piehslinger, 2013; Malo, Araújo Nobre, Lopes, & Rodrigues, 2015; Malo, de Araújo Nobre, Lopes, Ferro, & Gravito, 2016; Mertens & Steveling, 2011; Purcell, McGlumphy, Holloway, & Beck, 2008; Purcell, McGlumphy, Yilmaz, Holloway, & Beck, 2015; Romanos, Gupta, Gaertner, & Nentwig, 2014; Rosén & Gynther, 2007). Descriptive data regarding the characteristics of included studied were reported in Tables 2 and 3.

3.3 | Risk of bias

The risk of bias summary is presented in Table 4 and Figure 2 for the studies about FACFDP (total cantilevered fixed dental prosthesis). Among the studies about FACFDP 10 were classified as high risk of bias (Cid et al., 2014; Crespi et al., 2014; Fischer & Stenberg, 2011; Hellem et al., 2001; Malo et al., 2015; Mertens & Steveling, 2011; Purcell et al., 2008, 2015; Romanos et al., 2014; Rosén & Gynther,

TABLE 5 Annual failure rates and survival of implants/ICFDPs (full-arch prostheses)

Study	No. implants/ICFDPs available for the analysis (patients)	Mean follow-up time (years)	No. failures implants/ICFPDs	Total implants/ICFDPs exposure time
Cid et al. (2014)	110/42 (42)	5	NR/NR	550/NE
Crespi et al. (2014)	272/34 (28)	8	2/0	2176/272
Romanos et al. (2014)	203/31 (27)	6.5	5/1	1319.5/201.5
Fischer and Stenberg (2011)	132/23 (23)	10	7/4	1320/230
Mertens and Steveling (2011)	99/16 (16)	8.34	1/3	825.66/133.44
Gallucci et al. (2009)	237/45 (45)	5	0/2	1185/225
Hellem et al. (2001)	140/28 (28)	5	6/0	700/140
TOTAL prospective Summary estimate (95% CI)[a]				
Malo et al. (2016)	57/38 (33)	5.6	5/1	319.2/212.8
Purcell et al. (2015)	118/23 (23)	8.5	1/0	1003/195.5
Maló et al. (2015)	655/147 (104)	6.4	5/0	4192/940.8
Francetti, Corbella, et al. (2015)	380/95 (86)	5	2/13	1900/475
Krennmair et al. (2013)	152/38 (38)	5.5	0/0	836/209
Purcell et al. (2008)	233/46 (46)	7.9	1/0	1840.7/363.4
Rosén and Gynther (2007)	100/19 (19)	10	3/NR	1000/NE
TOTAL retrospective Summary estimate (95% CI)[a]				
TOTAL Summary estimate (95% CI)[a]				

Notes. ICFDPs: implant-supported, cantilever-fixed dental prostheses; MBL: marginal bone loss; NE: not estimable; NR: not reported.
[a]Based on random effects Poisson regression, test for heterogeneity (implants/ICFDPs), $p = 0.03/p = 0.93$.

2007) and 4 were classified as moderate risk of bias (Francetti, Corbella, et al., 2015; Gallucci et al., 2009; Krennmair et al., 2013; Malo et al., 2016).

3.4 | Full-arch rehabilitations

A total of 14 papers were selected and reported in Table 2 with mean follow-up ranging from 5 to 10 years (Cid et al., 2014; Crespi et al., 2014; Fischer & Stenberg, 2011; Francetti, Corbella, et al., 2015; Gallucci et al., 2009; Hellem et al., 2001; Krennmair et al., 2013; Malo et al., 2015, 2016; Mertens & Steveling, 2011; Purcell et al., 2008, 2015; Romanos et al., 2014; Rosén & Gynther, 2007). Seven prospective and seven retrospective studies were analysed. A total of 625 prosthesis supported by 2,888 implants in 558 patients were analysed. The rehabilitations were supporting bilateral cantilevers except for three studies that had also monolateral cantilever. Five papers focused on mandible rehabilitations, three on maxilla rehabilitations and six on both.

All studies reported on survival rate of implant and prosthesis except for one (Cid et al., 2014). Thirty-eight implants out of 2,888 and 24 prosthesis out of 625 failed. Three implants were lost due to severe peri-implantitis, seven due to overloading, three due to lack of osseointegration, four due to severe MBL and twenty-three due to no specified reasons. All the 24 prosthetic failures were due to the framework fracture. The estimated 5 to 10 years survival rate was calculated to be 99.00% (97.02; 99.71, 95% CI) and 96.7% (93.30; 99.56, 95% CI) for the implants and the prosthesis, respectively (Table 5). Prospective studies reported a 5–10 years survival rate of 98.7% (96.62, 100, 95% CI) and 95.8% (90.68; 100.4, 95% CI) at implant and prosthesis level, respectively. Retrospective studies reported 5–10 years survival rate of 99.2% (95.84; 101, 95% CI) and 97.1% (91.58, 103.1, 95% CI) at implant and prosthesis level, respectively.

A total of 299 complications (technical and biological) were reported with a cumulative 5–10 years complication rate of 44.41% (24.2; 61.1, 95% CI) and 39.46% (22.77; 59.37, 95% CI) for the patients and for the prosthesis, respectively (Table 6). Prospective studies reported a 5–10 years complications rate of 36.35% (1.29; 70.75, 95% CI) and 34.11% (0.62; 70.78, 95% CI) at patient and prosthesis level, respectively. Retrospective studies reported 5–10 years complications rate of 48.47% (21.05; 75.62, 95% CI) and 41.95% (18.72; 72.62, 95% CI) at patient and prosthesis level, respectively.

Implant/abutment-related technical complications were reported in 10 studies (Table 7). No implant fractures were described and therefore a cumulative 0% complications rate was calculated. By

Estimated failure rate (per 100 implants/ICFDPs years)	Estimated implant/ICFDP survival rate after 5–10 years	Mean MBL, mm	Estimated MBL after 5 years, mm
NE/NE	NE/NE	1.40	1.40
0.09/0.00	99.5%/100%	NR	NE
0.38/0.50	98.1%/97.5%	0.33	0.25
0.53/1.74	97.3%/91.3%	1.07	0.54
0.12/2.25	99.4%/88.8%	0.30 ± 0.72	0.18
0.00/0.89	100.0%/95.6%	NR	NE
0.86/0.00	95.7%/100%	NR	NE
	98.7% (96.62;100)/95.8% (90.68;100.4)		0.54 (−0.30;1.48)
1.57/0.47	92.2%/97.7%	1.79	1.60
0.10/0.00	99.5%/100%	NR	NE
0.12/0.00	99.4%/100%	1.52	1.19
0.11/2.74	99.5%/86.3%	0.45 ± 0.18	0.45
0.00/0.00	100.0%/100%	1.50	1.36
0.05/0.00	99.7%/100%	NR	NE
0.30/NE	98.5%/NE	1.20	0.60
	99.2% (95.84;101)/97.1% (91.58;103.1)		0.97 (0.43;1.65)
	99.0 (97.02;99.71)/96.7 (93.30;99.56)		0.85 (0.42, 1.26)

contrast abutment or screw fractures were described in three studies leading to a cumulative 5 to 10 years complications rate of 6.91% (−1.76; 13.54, 95% CI). Prospective studies reported a 5–10 years complications rate of 5.02 (−12.23; 19.64, 95% CI), while retrospective studies reported 5–10 years complications rate of 7.59% (−5.22; 19.29, 95% CI).

Restoration-related technical complications were reported in 12 studies (Table 8). One study reported on cemented restorations (31 restorations followed for 6.5 years with no decementations) while other six studies reported on screw-retained restorations (347 restorations followed for 5 to 8.5 years) with an estimated 5–10 years screw loosening rate of 5.01% (−11.30; 40.50, 95% CI). Ten studies (492 rehabilitations followed for 5 to 10 years) reported on framework fractures with a cumulative 5 to 10 years complications rate of 2.83 (−0.58, 5.044, 95% CI). Twelve studies (536 rehabilitations followed for 5 to 10 years) reported on veneer fractures with a cumulative 5 to 10 years complications rate of 25.66 (11.39, 35.55, 95% CI). Only two studies reported on ceramic veneering for full-arch cantilever restoration. The calculated 5 years chipping rate was 3.75% (−6.57, 13.9, 95%CI). Eight studies reported on metal-resin full-arch cantilever restorations. The calculated 5 years veneer fracture rate was 37.32% (14.8, 50.1, 95%CI).

Biological complications were reported in eight studies (Table 9). A total of 21 cases of peri-implantitis were reported in 8 studies (302 restorations followed for 5 to 10 years) and a total of 38 cases of mucositis were reported in 3 studies (restorations followed for 5 to 10 years). The cumulative 5–10 years complication rate was 3.37 (0.47, 5.59) for the implants and 15.78 (2.00, 22.68) for the prosthesis (95% CI).

Marginal bone loss (MBL) was reported in nine studies with a range from 0.30 to 1.79 mm. The estimated MBL after 5 years was of 0.85 mm (0.42, 1.26 mm, 95% CI; Table 5). Prospective studies reported an estimated 5-year marginal bone loss of 0.54 mm (−0.30; 11.48, 95% CI), while retrospective studies reported a MBL of 0.97 mm (0.43; 1.65, 95% CI).

Only one study (Krennmair et al., 2013) reported on MBL of the implants close to the cantilever (1.24 ± 0.32 mm) and that of the implants distant from the cantilever (1.17 ± 0.26 mm).

In six studies rehabilitations were supported by Brånemark System Implants (1543 implants and 368 rehabilitations), in three studies rehabilitations were supported by Straumann Dental Implants System (509 implants and 96 rehabilitations) and the remaining five studies by Sweden & Martina (272 implants and 34 rehabilitations), Ankylos (203 implants and 31 rehabilitations), Camlog (152 implants and 38 rehabilitations), Astra Tech Dental Implant System (99 implants and 16 rehabilitations) and Connexao Sistemas de Protese and Neodent (110 implants and 42 rehabilitations; Table 3).

TABLE 6 Overall complications (full-arch prostheses)

Study	No. implants/ICFDPs available for the analysis (patients)	Mean follow-up time (years)	Tot patients exposure time	Total prostheses exposure time	Total No. complications	Estimated complication rate (per 100 patients years)	Estimated complication rate (per 100 prostheses years)
Cid et al. (2014)	110/42 (42)	5	210	210	NR	NE	NE
Crespi et al. (2014)	272/34 (28)	8	224	272	2	0.89	0.74
Romanos et al. (2014)	203/31 (27)	6.5	175.5	201.5	3	1.71	1.49
Fischer and Stenberg (2011)	132/23 (23)	10	230	230	19	8.26	8.26
Mertens and Steveling (2011)	99/16 (16)	8.34	133.44	133.44	3	2.25	2.25
Gallucci et al. (2009)	237/45 (45)	5	225	225	34	15.11	15.11
Hellem et al. (2001)	140/28 (28)	5	140	140	21	15.00	15.00
Cumulative 5–10 year complication rate (95% CI)[a] -Prospective studies						36.35% (1.29. 70.75)	34.11% (0.62. 70.78)
Malo et al. (2016)	57/38 (33)	5.6	184.8	212.8	7	3.79	3.29
Purcell et al. (2015)	118/23 (23)	8.5	195.5	195.5	34	17.39	17.39
Maló et al. (2015)	655/147 (104)	6.4	665.6	940.8	35	5.26	3.72
Francetti et al. (2015)	380/95 (86)	5	430	475	77	17.91	16.21
Krennmair et al. (2013)	152/38 (38)	5.5	209	209	17	8.13	8.13
Purcell et al. (2008)	233/46 (46)	7.9	363.4	363.4	38	10.46	10.46
Rosén and Gynther (2007)	100/19 (19)	10	190	190	9	4.74	4.74
Cumulative 5–10 year complication rate (95% CI)[a] -Retrospective studies						48.47% (21.05, 75.62)	41.95% (18.72, 72.62)
Total cumulative 5–10 year complication rate (95% CI)[a]						44.41% (24.2, 61.1)	39.46% (22.77, 59.37)

Notes. ICFDPs: implant supported, cantilever-fixed dental prostheses; NE: not estimable; NR: not reported.
[a]Based on random effects Poisson regression, test for heterogeneity for complications (per patients/prostheses), $p = 0.01/0.08$.

TABLE 7 Implant/abutment-related technical complications (full-arch prostheses)

Study	No. implants available for the analysis (patients)	Mean follow-up time (years)	Total implants exposure time	No. of implant fracture	Estimated rate of implant fractures (per 100 implants years)	No of abutment or screw fracture	Estimated rate of abutment or screw fractures (per 100 patients/year)
Cid et al. (2014)	110 (42)	5	550	NR	NE	NR	NE
Crespi et al. (2014)	272 (28)	8	2176	NR	NE	NR	NE
Romanos et al. (2014)	203 (27)	6.5	1319.5	0	0.00	NR	NE
Fischer and Stenberg (2011)	132 (23)	10	1320	NR	NE	NR	NE
Mertens and Steveling (2011)	99 (16)	8.34	825.66	0	0.00	0	0.00
Gallucci et al. (2009)	237 (45)	5	1185	0	0.00	5	2.22
Hellem et al. (2001)	140 (28)	5	700	0	0.00	0	0.00
Cumulative 5–10 year complication rate (95% CI)[a] -Prospective studies					0.00		5.02 (−12.23, 19.64)
Malo et al. (2016)	57 (33)	5.6	319.2	0	0.00	0	0.00
Purcell et al. (2015)	118 (23)	8.5	1003	0	0.00	11	5.63
Maló et al. (2015)	655 (104)	6.4	4192	NR	NE	NR	NE
Francetti, Corbella, et al. (2015)	380 (86)	5	1900	0	0.00	0	0.00
Krennmair et al. (2013)	152 (38)	5.5	836	0	0.00	0	0.00
Purcell et al. (2008)	233 (46)	7.9	1840.7	NR	NE	10	2.75
Rosén and Gynther (2007)	100 (19)	10	1000	0	0.00	NR	NE
Cumulative 5–10 year complication rate (95% CI)[a] -Retrospective studies					0.00		7.59 (−5.33, 19.29)
Cumulative 5–10 year complication rates (95% CI)[a]					0.00		6.91 (−1.76, 13.54)

Notes. ICFDPs: implant-supported, cantilever-fixed dental prostheses; NE: not estimable; NR: not reported.
[a]Based on random effects Poisson regression, test for heterogeneity NA for implant fractures, $p = 0.43$ for abutment screw fractures.

TABLE 8 Restoration-related technical complications: veneer/framework fractures and decementation/screw loosening (full-arch prostheses)

Study	No. of ICFDPs available for the analysis (patients) C/R/V/NR	Mean follow-up time (yrs)	Total ICFDPs exposure time	No. of veneer/ framework) fractures	Estimated rate of veneer fractures (per 100 patients/year)	Estimated rate of framework fractures (per 100 patients/year)	No. of cemented ICFDPs available for loss of retention analysis
Cid et al. (2014)	42 NR (42)	5	210	NR	NE	NE	NA
Crespi et al. (2014)	34 C (28)	8	272	2/NR	0.89	0.00	NR
Romanos et al. (2014)	31 C (27)	6.5	201.5	0/1	0.00	0.57	31
Fischer and Stenberg (2011)	23 R (23)	10	230	16/2	6.96	0.87	NA
Mertens and Steveling (2011)	16 R (16)	8.34	133.44	3/0	2.25	0.00	NA
Gallucci et al. (2009)	45 V (45)	5	225	21/2	9.33	0.89	NA
Hellem et al. (2001)	28 R (28)	5	140	0/0	0	0	NA
Cumulative 5–10 year complication rates (95% CI)[a]Prospective studies					18.62 (−4.59, 36.97)	2.22 (−0.42, 5.08)	
Malo et al. (2016)	23R 15C (33)	5.6	212.8	1/0	0.54	0.00	NA
Purcell et al. (2015)	23 R (23)	8.5	195.5	19/0	9.72	0.00	NA
Maló et al. (2015)	147 V(104)	6.4	940.8	27/0	4.06	0.00	NA
Francetti, Corbella, et al. (2015)	95 R (86)	5	475	29/13	6.74	3.02	NA
Krennmair et al. (2013)	38 R (38)	5.5	209	17/NR	8.13	NE	NA
Purcell et al. (2008)	46 R (46)	7.9	363.4	28/0	7.71	0.00	NA
Rosén and Gynther (2007)	19 R (19)	10	190	NR	NE	NE	NA
Cumulative 5–10 year complication rates (95% CI)[a] Retrospective studies					29.54 (13.30, 48.20)	3.17 (−5.37, 11.42)	
Cumulative 5–10 year complic. rates (95% CI)[a]					25.66 (11.39, 35.55)	2.83 (−0.58, 5.044)	
Cumulative 5-year fracture rate ceramic/ resin veneers				Ceramic: 3 resin: 127	3.75 (−6.57, 13.9) 37.32(14.8, 50.1)		

Notes. Based on random effects Poisson regression, test for heterogeneity $p = 0.14$ for veneers fractures, $p = 0.27$ for framework fractures, NA for loss of retention, $p = 0.70$ for screw loosening.
C, ceramic; CI, confidence interval; ICFDPs, implant-supported, cantilever-fixed dental prostheses; NA, not applicable; NE, not estimable; NR, not reported; R, resin; V, various.

4 | DISCUSSION

The focused question of the present review was "In what clinical situations are cantilever a successful treatment modality?". A literature search was carried out with the aim of finding results for fully and partially edentulous patients. Both retrospective and prospective studies were selected, with a minimum follow-up of 5 years and at least 10 patients.

Fully edentulous situations treated with implant-supported fixed reconstructions with cantilever (FAICFDP) were considered in the present paper. The screening phase was quite complicated by the fact that several papers did not specifically report on cantilever restorations. By contrast, the paper was showing images and radiographs of cantilevered rehabilitations. Several emails were sent to the authors with the intent to clarify the content and the restorations that were used. The answers were quite scarce and very few authors were able to help in retrieving additional data for this review. Therefore, several papers were excluded since no data on cantilever was retrievable nor it was possible to differentiate between cantilever and non-cantilever restorations.

In the present review, an estimated implant and prosthesis survival rate after 5–10 years was calculated to be 99.00% and 96.7%, respectively. Fourteen prospective and retrospective studies concerning implant-supported complete cantilevered prothesis with 5–10 years of follow-up were included. A total of 558 patients, 625 full-arch prostheses and 2888 implants were analysed. It must be said that several excluded studies that were retrieved for full-text analysis reported images of full-arch prosthesis with cantilevers, but the text did not cite their presence nor it was not possible to extrapolate any more specific data even after writing to the authors. In a recent review by Papaspyridakos et al. (2014), the authors screened the literature for articles about full-arch rehabilitations in the mandible and considered both cantilevered and non-cantilevered

Total cemented ICFDPs exposure time	No. of cases of loss of retention	Estimated rate of loss of retention (per 100 ICFDP year)	No. of screw-retained ICFDPs available for screw loosening analysis	Total screw-retained ICFDPs exposure time	No. of cases of screw loosen-ing	Estimated rate of screw loosening (per 100 screw-retained ICFDP year)
NA	NA	NA	42	210	NR	NE
NE	NR	NE	NR	NE	NR	NE
201.5	0	0.00	NA	NA	NA	NA
NA	NA	NA	23	230	NR	NE
NA	NA	NA	16	133.44	0	0.00
NA	NA	NA	45	225	NR	NE
NA	NA	NA	28	140	18	12.86
						32.91 (−376, 441)
NA	NA	NA	38	212.8	3	1.41
NA	NA	NA	23	195.5	4	2.05
NA	NA	NA	147	940.8	8	0.85
NA	NA	NA	95	475	0	0.00
NA	NA	NA	38	209	NR	NE
NA	NA	NA	46	363.4	NR	NE
NA	NA	NA	19	190	NR	NE
						4.11 (−1.52, 12.29)
		0.00				5.01 (−11.30, 40.50)

restorations. The author underlined that all of their 17 prospective included papers reported about cantilevered rehabilitations in the edentulous mandible. In the present systematic review, not all of the studies included in the 2014 review were included.

For implant-supported fixed dental prostheses, the incorporation of cantilevers could be associated with a higher incidence of complications. The present systematic review revealed a cumulative 5 to 10 years prosthetic complication rate of 39% (34% in prospective studies and 42% in retrospective studies. Complication rate at patient level are 44% (36% for prospective and 48% in retrospective studies) These results can be compared with the review from Papaspyridakos, Chen, Chuang, Weber, and Gallucci (2012) that reported a 10-year cumulative rate of "prosthesis free of complications" of 8.6% for full-arch restorations. Although the figures appear to be different, the rate of complications is in both cases quite high, suggesting that more attention need to be paid on prosthetic aspects of the rehabilitation, such as material, retrievability and fixation.

In our review, screw-retained restorations were the most common. Only the papers by Romanos et al. (2014) and Crespi et al. (2014) reported on cement retained FAICFDP. No direct comparison with cement retention could be carried out due to the small number of reported cement-retained FAICFDP.

Eight studies have reported on metal resin screw-retained restorations, two on ceramic veneering and three on both. The clinical use of resin could be due to the lower production cost compared to a metal-ceramic one. No data on zirconia framework with cantilever was reported. It must be noted that the metal-resin restorations showed more technical complications mail related to the fracture of the veneering. Patients and clinicians should be aware that metal-resin reconstruction have high rate of survival rate but demonstrate high number of complications. Nevertheless, a fracture of the resin veneering could be more easily managed in the office in terms of procedure, chair-side time and economical costs rather than a ceramic chipping. It was not possible to differentiate between

TABLE 9 Biological complications (full-arch prostheses)

Study	No. implants/ICFDPs available for the analysis (patients)	Mean follow-up time (years)	Total implants/ICFDPs exposure time	No. of biological complications (peri-implantitis)	Estimated implant/ICFDP complication rate (per 100 implants/prostheses years)
Cid et al. (2014)	110/42 (42)	5	550/NE	NR	NE
Crespi et al. (2014)	272/34 (28)	8	2176/272	NR	NE
Romanos et al. (2014)	203/31 (27)	6.5	1319.5/201.5	2 (2)	0.15/0.99
Fischer and Stenberg (2011)	132/23 (23)	10	1320/230	1 (1)	0.08/0.43
Mertens and Steveling (2011)	99/16 (16)	8.34	825.66/133.44	NR	NE
Gallucci et al. (2009)	237/45 (45)	5	1185/225	6 (3)	0.51/2.67
Hellem et al. (2001)	140/28 (28)	5	700/140	3 (3)	0.43/2.14
Cumulative 5–10 year complication rate (95% CI)[a] Prospective studies					1.33 (−0.21, 3.11) 7.53 (−1.38, 10.59)
Malo et al. (2016)	57/38 (33)	5.6	319.2/212.8	3 (3)	0.94/1.41
Purcell et al. (2015)	118/23 (23)	8.5	1003/195.5	0	0.00/0.00
Maló et al. (2015)	655/147 (104)	6.4	4192/940.8	NR	NE
Francetti, Corbella, et al. (2015)	380/95 (86)	5	1900/475	35 (9)	1.84/7.37
Krennmair et al. (2013)	152/38 (38)	5.5	836/209	NR	NE
Purcell et al. (2008)	233/46 (46)	7.9	1840.7/363.4	NR	NE
Rosén and Gynther (2007)	100/19 (19)	10	1000/NE	9 (0)	0.90/4.74
Cumulative 5–10 year complication rate (95% CI)[a] Retrospective studies					5.57 (−0.36, 15.95) 21.90 (−9.51, 43.30)
Total cumulative 5–10 year complication rate (95% CI)[a]					3.37 (0.47, 5.59) 15.78 (2.00, 22.68)

Notes. ICFDPs: implant-supported, cantilever-fixed dental prostheses; NE: not estimable; NR: not reported.
[a]Based on random effects Poisson regression, test for heterogeneity, $p = 0.82$.

the severity of the veneer fracture of ceramic and resin. A recent RCT compared at 1 month a ceramic to a composite veneering in full-arch restorations. The one-month time frame was not sufficient to acknowledge differences in terms of complications. At the same time, the patients accepted better the ceramic veneering mail for the aesthetic provided. (Merli et al., 2017).

Biological complications were reported (8 papers) to have affected 16% of the restorations. Due to the absence of RCT, it is not possible to assess if this rate is due to the presence of the cantilever or not. Nevertheless, the incidence and the prevalence of mucositis and peri-implantitis can be quite high and need to be taken into consideration both in cantilevered and non-cantilevered full-arch reconstructions.

The high rate of technical and biological complications may rise the need for repairs and modifications. Therefore, scheduled a regimen of follow-up visits should be defined. The use of screw-retained full-arch reconstructions could be suggested, since the cemented reconstruction may be more difficult to retrieve.

One limitation of the present review was that studies with different designs (both retrospective and prospective studies) were selected and analysed together. This was done in order to consider the widest possible amount of data available for analysis but might have contributed to increase heterogeneity of the datasets. Moreover, the authors of the present review have the sense that underreporting is a major issue in the literature.

5 | CONCLUSIONS

Implant-supported restorations with cantilever appear to be able to provide a high survival rate of the restorations in fully edentulous patients. High rate of technical complications, mainly veneer fracture, were reported when metal-resin rehabilitations were involved.

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