Received: 3 December 2017 | Revised: 7 July 2018 | Accepted: 16 July 2018

DOI: 10.1111/joor.12695

REVIEW

WILEY Journal of Oral Rehabilitation

Complications and survival rates of inlays and onlays vs complete coverage restorations: A systematic review and analysis of studies

Georgia I. Vagropoulou[1] | Georgia L. Klifopoulou[2] | Stefania G. Vlahou[2] | Hiroshi Hirayama[3] | Konstantinos Michalakis[1,4]

[1]Department of Prosthodontics, Division of Graduate Prosthodontics, School of Dentistry, Aristotle University of Thessaloniki, Thessaloniki, Greece

[2]School of Dentistry, Aristotle University of Thessaloniki, Thessaloniki, Greece

[3]Department of Restorative Sciences and Biomaterials, Division of Graduate Prosthodontics, Henry M Goldman School of Dental Medicine, Boston University, Boston, Massachusetts

[4]Department of Prosthodontics, Division of Graduate and Postgraduate Prosthodontics, School of Dental Medicine, Tufts University, Boston, Massachusetts

Correspondence: Konstantinos Michalakis, Department of Prosthodontics, Division of Graduate Prosthodontics, School of Dentistry, Aristotle University of Thessaloniki, University Campus, Thessaloniki 54124, Greece (kmichalakis@hotmail.com).

Summary

Objective: The aim of this study was to identify if different types of indirect restorations used for single teeth had different biological and technical complications, as well as survival rates.

Method: An electronic search was performed in various electronic databases to identify articles, published between 1980 and 2017. The search terms were categorised into 4 groups: inlay, onlay, inlay/onlay and crown. Manual searches of published full-text articles and related reviews were also performed.

Results: A total number of 2849 papers were retrieved initially. After a detailed assessment for eligibility, 9 studies were selected for inclusion. The heterogeneity of the studies did allow neither a meta-analysis nor any meaningful comparison between types of restorations or materials. Only some pooling was performed for representative reasons. The mean survival rate of inlays was 90.89%, while for onlays and crowns it was 93.50% and 95.38%, respectively. For the fourth study group, consisting of both inlays and onlays, the survival rate was found to be 99.43%. Statistical analysis demonstrated caries to be the main biological complication for all types of restorations, followed by a root and/or tooth fracture incidence (11.34%) and endodontic incidence. Ceramic fractures represented the most common technical complication, followed by loss of retention and porcelain chipping.

Conclusion: The 5-year survival rate for crowns and inlays/onlays is very high, exceeding 90%. An association between the kind of complications and different types of restorations could not be established. Nevertheless, a relatively high failure rate due to caries and ceramic fractures was noted.

KEYWORDS

complications, crown, inlay, onlay, survival rates, tooth

1 | INTRODUCTION

Although caries is the predominant reason for loss of tooth structure, several other non-carious lesions, such as erosion, abfraction, attrition and fracture may also lead to breakdown of the hard tissues of the teeth, necessitating their restoration.[1,2] Developmental tooth malformation may also require an intervention, in order for the tooth's shape or structure to be restored for biological, functional, aesthetic or social reasons.[3] As life expectancy has been improved globally, and adults in developed countries tend to maintain their natural dentition, it is expected that the need for restorative work will increase in the future.[4,5] As the conditions of dental health and the needs of individual patients vary widely, the selection of the proper restorative procedure and material seems to be imperative in cases of tooth substance loss.[6]

There are 2 types of restorations that can usually be used to restore a tooth: (a) direct and (b) indirect.[7-9] Every type of restoration has its indications and contraindications, as well as its advantages and disadvantages.[10,11] Complete coverage restorations are used extensively in everyday clinical practice, especially when tooth structure loss is more than 50%.[12] Gold, metal ceramic, all ceramic and zirconia crowns have been used successfully and they all represent different restorative material options.[13-15] Cast gold metal crowns were very popular in the past due to their excellent resistance to corrosion, minimal preparation requirements, ease of handling and finishing, exact reproduction of tooth's anatomy, support and protection of the enamel margins of the tooth, durability and longevity.[16] Their inferior aesthetics can pose a problem, especially in visible areas, such as the posterior teeth of the mandibular arch.

Since their introduction in the mid-1950s, metal ceramic crowns have been used extensively [17-19] demonstrating a survival rate of 94.7%, according to a systematic review which included prospective and retrospective studies with a mean follow-up period of at least 3 years.[20]

All ceramic restorations became very popular due to their translucency and enhanced aesthetic properties and can be predominantly glass, particle-filled glass or polycrystalline.[21] Predominantly glass ceramics include feldspathic porcelain which can be used for fabrication of all ceramic restorations, including crowns, veneers, inlays and onlays. Their principal disadvantage is the low fracture toughness and flexural strength.[22-24] Particle-filled ceramics and polycrystalline can be both employed as core materials in bilayered all-ceramic restorations. Their principal difference is the opacity of polycrystalline, which makes it unsuitable for monolithic restorations.[25,26] Besides the composition of the ceramic material, other parameters related to patients (age, gender, tooth history, frequency of treatment, carries and periodontal indices), dentists (age, gender and level of expertise) as well as tooth position in the arch may affect the survival rates.[27,28] A systematic review has demonstrated that anterior teeth present higher survival rates than posterior ones. For the ceramic systems Empress (Ivoclar Vivadent, Liechtenstein) and InCeram (VITA Zahnfabrik, Germany) the survival rates were 84.4% vs 94.5%, and 90.4% vs 94.5%, respectively.[29]

Zirconia (yttria-stabilised zirconia polycrystal) restorations are also used extensively, mainly because of their increased strength and fracture toughness, combined with their "metal free" nature.[30] Their fracture strength, however, depends on whether the restorations are monolithic or bilayered. Monolithic restorations failures occur very rarely. A 2-year randomised controlled clinical trial and a 3-year retrospective study have demonstrated survival rates of 96.6% and 100%, respectively.[31,32] Unfortunately, the success rates of bilayered zirconia restorations do not come close to the monolithic ones.[33,34] Although the zirconia core may not break, the aesthetic veneers may chip or fracture, influencing negatively the success rates of the restorations. The survival rates may also be influenced, if the delamination of the veneering material is extended. It should be mentioned however that the fracture of the veneering material occurs in other all ceramic systems too. Research has demonstrated that layered lithium disilicate crowns fractured at ~2 times the rate of monolithic lithium disilicate crowns.[35]

The aforementioned materials can be used for both partial and full coverage restorations as well. Cast gold has been used for many years successfully not only for crowns, but for inlays and onlays as well.

A clinical study on 50 patients and 303 gold inlays and onlays has demonstrated a failure rate of 13.8% for a mean observation period of 18.7 years.[36] Another study of 391 gold onlays and inlays, in 138 patients has presented a 6.4% failure rate for a mean follow-up period of 11.6 years.[37]

Ceramic inlays and onlays present very high survival rates too. A retrospective study on leucite-reinforced (IPS Empress; Ivoclar Vivadent, Schaan, Liechtenstein). Leucite-reinforced inlays and onlays delivered to 390 patients by 244 operators and followed for a period of up to 9.6 years has shown a survival rate of 96.7%.[38] A recent systematic review and meta-analysis on resin and ceramic inlays, onlays and overlays has concluded that the estimated survival rates for glass ceramics and feldspathic porcelain ranged between 92% and 95% for 5811 restorations at 5 years, while for the 10-year period, the survival rate for 2154 restorations was 91%.[39]

Failures in both complete and partial coverage restorations are related to fractures/chipping, endodontic complications, recurrent decay, retention loss and in cases of all-ceramic restorations severe marginal staining may result as well.

Both complete and partial coverage restorations have been employed in the past for the restoration of posterior teeth. However, a comparison between those types of restorations regarding their survival rate and associated complications has not been thoroughly evaluated. Therefore, the decision as to which type of restoration and restorative material should be adopted is sometimes difficult and very often a matter of personal preference rather than of scientific evidence. In order for the restorative dentists to be able to use both types of restorations and restorative materials, these should present comparable clinical results.

The purpose of this systematic review, therefore, was to identify clinical studies in which crowns and inlays/onlays were used to restore damaged teeth and compare their biological and technical complications, as well as their survival rates.

2 | MATERIALS AND METHODS

The PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines for reporting data regarding healthcare interventions were used for the purposes of the present study.[40]The focused PICO (population, intervention, control, outcome) question of the present systematic review was whether the different types of restorations (complete coverage vs inlays and onlays) used for damaged teeth had different biological and technical complications, as well as their survival rates (Figure 1). The study protocol was established first, by conducting a pilot initial PubMed search followed by a systematic assessment of 5 potentially eligible studies, which were randomly selected. This preliminary search revealed that randomised controlled studies on that subject would be very limited or even not existing. Therefore, an eligibility assessment of non-randomised clinical studies, after a detailed quality evaluation protocol, was adopted.[40]

2.1 | Search strategy

The detailed search strategy was:

Population: "single person"[MeSH], "tooth"[MeSH], "wounds and injuries"[MeSH], "dental caries"[MeSH], "fractures"[MeSH], "tooth fractures"[MeSH]

(single damaged teeth) OR (single damaged tooth) OR (single restored teeth) OR (single restored tooth) OR (solitary restored tooth) OR (solitary restored teeth) OR (trauma tooth) OR (trauma teeth) OR (decayed tooth) OR (decayed teeth) OR (fractured teeth) OR (fractured tooth) OR (broken tooth) OR (broken teeth) OR (cracked tooth) OR (cracked teeth)

Intervention: "inlay" [MeSH], "onlay" [MeSH]

(inlay*) OR (onlay*) OR (3/4 crown*) OR (4/5 crown*) OR (7/8 crown*) OR (partial coverage restoration*)

Control: "crown" [MeSH]

(crown*) OR (full coverage restoration*) OR (complete coverage restoration)

Outcome: "Cracked Tooth Syndrome" [MeSH], "tooth substance loss" [MeSH], "survival rate" [MeSH]

(technical failure) OR (biological complication*) OR (fracture*) OR (crack*) OR (cracked tooth syndrome*) OR (success) OR (success rate) OR (survival) OR (survival rate) OR (tooth substance loss)

An electronic Medline search was performed to identify English language articles published from January 1980 to July 2017, by 2 independent reviewers (GV and GK; Figure 2). This time frame was selected in an effort to include restorative materials that are currently in use.[41] A further electronic searching was carried out in Scopus and EMBASE databases. Specific key words, as well as various combinations of those key words were used for the establishment of the appropriate studies, which were recorded within the characteristics of the specific PICO previously described. The electronic search was supplemented by a manual search of the same time period issues of the following journals: Journal of Prosthodontics, Journal of Prosthetic Dentistry, International Journal of Prosthodontics, International Journal of Periodontics and Restorative Dentistry, Journal of Operative Dentistry, Journal of Oral Rehabilitation and Clinical Oral Investigations.

2.2 | Eligibility criteria

2.2.1 | Inclusion criteria

The aim of this search was to find randomised clinical trials (I-IV) [42] comparing inlays/onlays and complete coverage restorations.[43] However, other clinical studies, including prospective, retrospective cohort studies, as well as case series were identified too.

Additional inclusion criteria were the following:

- The studies included a clinical and/or radiographic examination of the outcome and had an absolute mean follow-up time of the restoration of at least 1 year.[44]
- The studies included at least 1 type of partial restoration (inlay or onlay) directly compared to a complete coverage restoration.
- The studies reported on the presence or absence of biologic and/or prosthetic (technical) complications at the follow-up.
- The studies contained numeric data regarding the total number of each restoration and the total number of failures.

2.2.2 | Exclusion criteria

All clinical studies which did not satisfy the aforementioned criteria, ie, animal studies, in vitro studies, in silico studies, systematic reviews, reviews, expert opinions, case reports, clinical studies with <1-year follow-up, and clinical studies which reported data based on questionnaires and interviews were excluded. Studies which did not compare directly partial to complete coverage restorations were also excluded.

2.3 | Selection of studies

The guidelines for the screening and selection of the articles to be included in this systematic review were set before initiation of the search. An electronic and hand search was performed in July 2017, and the initial amount of papers was screened by title from the 2 principal investigators (GV, GK) individually. After the exclusion at title level and removal of the duplicates, the remaining bulk of studies was screened by abstract, for possible inclusion in the review, based on the exclusion criteria formerly set. Any disagreement was resolved by discussion with the other participating authors.[40] Moreover, if not enough information was provided in either the title or the abstract, the full text was obtained to include all relevant articles. Additionally, all references included in the selected articles were evaluated. The full text of all possibly relevant studies was then obtained for independent assessment by each reviewer. The eligibility criteria were applied

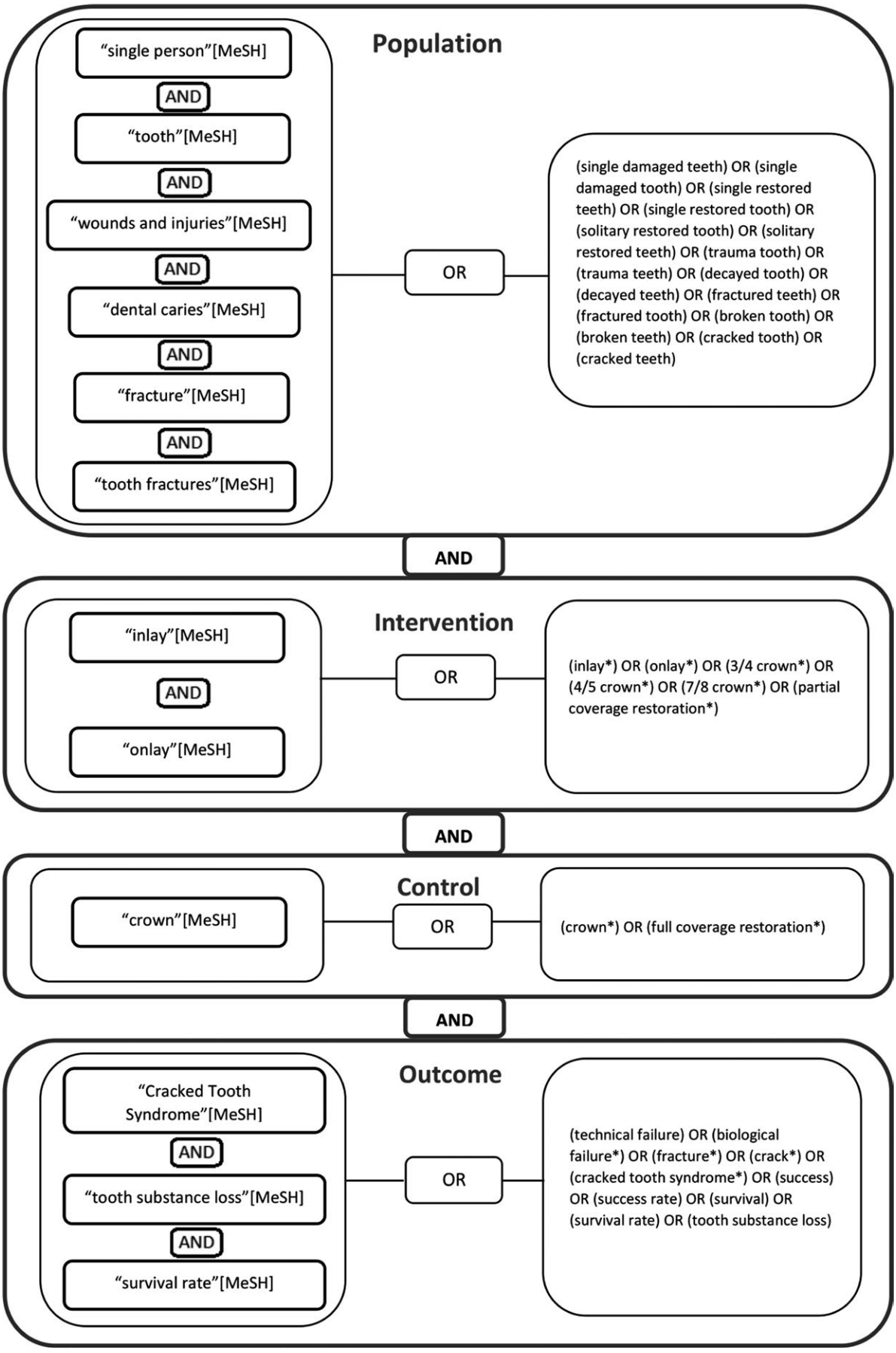

FIGURE 1 PICO question

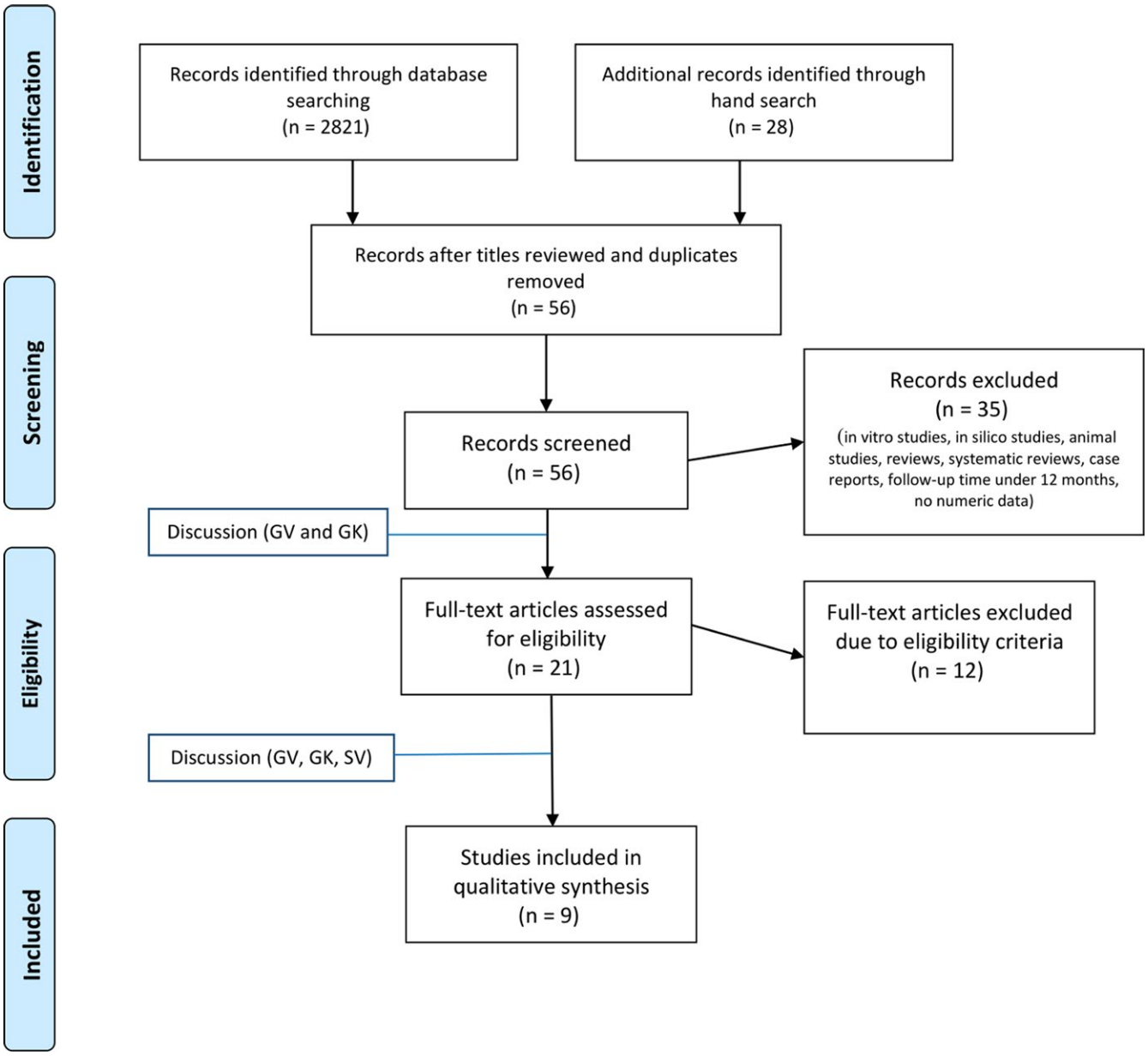

FIGURE 2 Flow Chart [Colour figure can be viewed at wileyonlinelibrary.com]

to identify the final articles which would be used for this systematic review. The 2 principal investigators (GV, GK) came to an agreement on the articles which would be included in this systematic review. Following that, a final control was conducted by the third reviewer (SV), who assessed each one of the selected studies for its eligibility, according to the set criteria. All 3 reviewers agreed on the selection of the articles to be included (Figure 2, Table 1).

2.4 | Data extraction

Information on the survival rates and on the biological and technical complications of the restorations was extracted from the included studies. The number of events and the corresponding total time of service of restorations were calculated. An assessment of the diagrams existing in each study was performed by all 3 reviewers independently, using the rule of three. Thus, numeric data were extracted from each study included in this review. In those cases that data were insufficient the authors of the articles were contacted by means of email. Survival was defined as the restoration remaining in situ for the observation period with or without modifications.[45-53] The analysis of the technical complications included chipping, fracture or crack of the ceramic, loss of retention, core failure and marginal integrity. The analysis of the biological complications included caries, tooth fracture, root fracture, hypersensitivity and pulpitis or other damage of the pulp, which led to endodontic treatment. The following parameters were studied by the 2 reviewers (GV and GK) and associated data were retrieved: setting; lead author; year of publication; journal of publication; study design; total

TABLE 1 Detailed information of the 9 studies included in the present systematic review

Authors	Year	Journal	Study design	Gender		Age	Setting	Evaluation criteria	Inclusion criteria
				Men	Women				
Barnes et al	2010	AJD	Prospective clinical trial	N.m.	N.m.	N.m.	University	Modified USPHS	N.m.
Djiken et al	2010	ADM	Prospective clinical trial	46/121	75/121	26-81	Private/University	Modified USPHS	N.m.
Riech et al	2004	JADA	Prospective clinical trial	18/26	8/26	18-77	University	USPHS/Modified USPHS	Extensive tooth destruction
Sulaiman et al	2015	JPD	Retrospective Study	N.m.	N.m.	N.m.	Private	N.m.	N.m.
Fabbri et al	2014	Int J PRD	Retrospective Study	143/312	169/312	19-71	Private/University	Modified CDA	Good oral health, Sample including both vital and non-vital teeth, Natural teeth in the opposing dentition
Beier et al	2012	IJP	Retrospective Study	120/302	182/302	33.3-59.65	University	Modified CDA	Periodontal Health
Donovan et al	2004	JERD	Retrospective Study	39/114	75/114	31-91	Private	N.m.	N.m.
Kelly et al	2004	BDJ	Retrospective Study	N.m.	N.m.	28.44-52.38	Private	N.m.	N.m.
Heckland et al	2003	IJP	Retrospective Study	N.m.	N.m.	N.m.	Private	N.m.	N.m.

Authors	Total number of restorations			Location of restorations								
				Anterior			Premolars			Molars		
	Inlays	Onlays	Crowns	Inlays	Onlays	Crowns	Inlays	Onlays	Crowns	Inlays	Onlays	Crowns
Barnes et al	1	19	40			31/40	1/1	5/19	9/40		14/19	
Djiken et al	29	88	84				4/29	18/88	21/84	25/29	70/88	63/84
Riech et al		22	20		1/22	6/20		4/22	5/20		17/22	9/20
Sulaiman et al	1093		15.765	N.m.	N.m.	N.m.	N.m.	N.m.	N.m.	N.m.	N.m.	N.m.
Fabbri et al		62	428			231/428		62/62	197/428		62/62	197/428
Beier et al	334	213	470			334/470			103/470			33/470
Donovan et al	644	197	355	N.m.	N.m.	N.m.	N.m.	N.m.	N.m.	N.m.	N.m.	N.m.
Kelly et al		22	323			111/323			212/323			212/323
Hekland et al	1544		746			505/746	617/1544		119/746	927/1544		122/746

Authors	Material of restorations	Luting agent while cementation
Barnes et al	Leucite reinforced ceramic(all restorations)	Dual cure resin cement
Djiken et al	Leucite reinforced ceramic(all restorations)	1. Chemically cured resin 2. Dual curing composite system

(*Continues*)

TABLE 1 (Continued)

Authors	Material of restorations	Luting agent while cementation
Riech et al	1. Feldspathic ceramics(number of restorations not mentioned) 2. Leucite reinforced ceramics(number of restorations not mentioned)	1. Dual cure resin cement 2. Dual curing composite system
Sulaiman et al	1. Lithium disilicate monothic ceramic(1.093/1.093inlays-onlays, 11.603/15.765 crowns) 2. Lithium disilicate layered ceramic(4.162/15.765 crowns)	N.m.
Fabbri et al	1. Lithium disilicate monolithic ceramic(46/62 onlays-154/428 crowns) 2. Lithium disilicate layered ceramic(16/62 onlays-274/428 crowns)	1. Dual cure resin cement 2. Flowable composite resin 3. Dual curing composite system
Beier et al	Silicate ceramic	1. Dual cure resin cement(6/334 inlays-20/470 crowns) 2. Chemically cured resin(5/334 inlays-1/213 onlays-29/470 crowns) 3. Dual curing composite system(323/334 inlays-212/213 onlays-421/470 crowns)
Donovan et al	Cast gold(all restorations)	Zinc phosphate
Kelly et al	1. Feldspathic ceramic(18/323) 2. Ceramometal (212/323 crowns) 3. Cast gold(93/323 crowns-22/22 onlays)	N.m.
Hekland et al	1. Feld spathic ceramic(675/1.544 inlays-onlays, 487/746 crowns) 2. Leucite reinforced ceramic(869/1.544 inlays-onlays, 166/746 crowns) 3. Lithium disilicate ceramic(93/746 crowns)	N.m.

Authors	Mean follow up time/range	Total number of survived units			Total number of failed units			Type of failures	
		Inlays	Onlays	Crowns	Inlays	Onlays	Crowns	Biological complications	Technical complications
Barnes et al	36/6-36	0/1 (dropout at 24 mo)	15/16	35/36	0/1 (dropout at 24 mo)	1/16	1/36	Root-tooth fracture ● 1 crown	Ceramic fracture ● 1 onlay
Djiken et al	180/30-42	19/29	72/88	65/84	10/29	16/88	19/84	N.m.	N.m
Riech et al	36/30-42		21/22	20/20		1/22	0/20	Root-tooth fracture ● 1 onlay	
Sulaiman et al	45	1082/1093		15.583/15.765	11/1093		182/15765	N.m.	N.m
Fabbri et al	70/12-72		58/62	414/428		4/62	4/62	Endo treatment ● 1 crown Root-tooth fracture ● 1 crown	Ceramic fracture-core failure ● 10/14 crownsLoss of retention● 2/14 crowns● 1/4 onlaysChipping-marginal integrity ● 3/4 onlays

(*Continues*)

TABLE 1 (Continued)

Authors	Mean follow up time/range	Total number of survived units			Total number of failed units			Type of failures	
		Inlays	Onlays	Crowns	Inlays	Onlays	Crowns	Biological complications	Technical complications
Beier et al	240/42-240	313/334	208/213	433/470	21/334	5/213	37/470	Caries • 7/21 inlays • 1/5 onlays • 5/37 crowns Endo treatment • 2/21 • 1/5 • 2/37 Root-tooth fracture • 1/21 inlays • 3/37 crowns Hypersensitivity • 1/5 onlays • 1/37 crowns	Ceramic fracture-core failure • 9/21 inlays • 1/5 onlays • 24/37 crowns Chipping-marginal integrity • 2/21 inlays • 1/5 onlays • 2/37 crowns
Donovan et al	N/m/12-480	614/644	191/197	341/355	30/644	6/197	14/355	N.m.	N.m.
Kelly et al	180/60-180		0/22	255/323		22/22	68/323	N.m.	N.m.
Hekland et al	24/1-60	1.541/1.544		734/746	3/1544		12/746	N.m.	N.m.

number of restorations; type of restoration; restoration material; tooth location; luting agent; mean follow-up time; follow-up range; evaluation criteria; total number of failures; biological complications; technical failures. Data from all included studies were extracted independently by 3 authors (GV, GK, SV) using data extraction forms constructed by the authors in an Excel (Microsoft Corp., WA, USA) sheet. Disagreement regarding data extraction was resolved by discussion which led to a consensus between the 3 authors. Data plethora and space saving issues led to the categorisation of the most informative parameters only (lead author; year of publication; journal of publication; study design; gender and age of patient; setting; evaluation criteria; inclusion criteria; total number of restorations; type of restoration; tooth location; material of restoration; luting agent; mean follow-up time; follow-up range; total number of survived units; total number of failed units; type of failures) in the tables of the included studies. Therefore, the restorative materials and the luting agents were sorted as 6 and 5 general categories, respectively.

3 | ANALYSIS OF STUDIES

The restorations' survival rate (SR) was the primary outcome of the present study. The FR of the various types of specific failures (B.Caries, B.Endo, B.Fracture, B-sensitivity, T.Ceramic.Fracture, T.Chip, T.Retention) was the secondary one. Within the methodological frame of meta-analysis, *SR* and *FR* were considered as indices of effect size. In both cases, the contribution (weight) of each study in the analysis was based on the number of restorations and it was determined according to the following scheme: arms within studies were weighted according to the quantity $W = 1/SE$, with $SE = r/\sqrt{rN}$, where r is the SR or FR, as appropriate, of the arm (computed as ratios) and N is the total number of restorations used in the arm (for SR) or the total number of failures (for FR). Neyeloff et al [54] proposed the quantity $W^*=1/SE^2$ as an appropriate weight for rates. But, in the present study, the use of weight (W^*) had as a result some studies to dominate "unrealistically" over the others, because they were heavily "over-weighted." So, in order the results and the comparisons of the analysis to become more meaningful the weight W was finally used.

All statistical comparisons were carried out within the methodological frame of the random effects model of meta-analysis [55,56] in order to overcome probable bias resulted from methodological or other differences among the selected studies.[57] Differences among groups of studies were tested by the comparison of the estimated mean *SR* (or *FR*) according to the degree of overlap of the corresponding bias corrected bootstrap 95% confidence intervals (CIs). Groups were considered statistically significant different if the corresponding 95% CIs for mean SR (or FR) did not overlap.[58,59] A technical description for the use and computation of bias-corrected bootstrap CIs can be found in Rosenberg, Adams and Gurevitch.[60] Following Theodoridis et al,[57] although ANOVA results are reported in the manuscript, however, these results were not assessed because of the limited number of studies and the fact that there was

no evidence relative to the normality of the distribution of the effect size indices (*SR* or *FR*) used in the current analyses. The heterogeneity of studies was assessed with the *Q* test at significance level $P \leq 0.10$ [31] in order to increase the power of the test. A scatter plot was produced for the graphical representation of the association between *SR* and follow-up time (in months). Spearman's *rho* correlation coefficient was computed for evaluating the strength of association. Using SPSS v.15.0 (SPSS Inc., Chicago, Illinois) weighted smoothing curve using the Loess method [61] was also plotted on the corresponding scatter plot to verify the examined relationship. Generally, publication bias of various forms is almost assured, but fail-safe analyses cannot be trustworthily statistically tested and evaluated mainly due to the limited number of studies. MetaWin v.2.1 software was used for performing the present analysis.[60]

3.1 | Quality assessment of individual included studies

The assessment of the quality of evidence of the non-randomised clinical trials can be performed with various tools. In the present study, the Cochrane risk of bias tool for assessing the risk of bias of randomised clinical trials was utilised.[62] This tool basically consists of the "Risk of bias" table, which can be found in the RevMan software. According to this, each included study was judged based on 7 items/characteristics/entries and categorised as "low-," "high-" or "unclear-risk" of bias. The ended result of this judgement is the generation of the "Risk of bias summary" figure. Due to the fact that all the included studies would be non-randomised clinical trials (observational), it was decided not to include in the judgement the "random sequence generation (selection bias)" and "allocation concealment (selection bias)" items/entries and to default these as "unclear." Therefore, a modified figure was presented, which has been used, also, by other authors.[63]

It should be noted that the main aim of the present study was to accomplish a systematic review and if possible a meta-analysis. However, due to the limited number of comparable studies, the presented analysis of studies serves only to provide some numerical evidence to enhance the discussion.

4 | RESULTS

4.1 | Study characteristics

The electronic and manual search of the literature provided an initial bulk of 2849 studies. Further screening of the article titles performed by the 2 principal investigators (GV, GK) resulted in 56 potentially relevant studies. Independent evaluation at abstract level resulted in the exclusion of 35 articles, as they did not meet the inclusion criteria. Full-text screening resulted in inclusion of 9 out of 21 studies regarding the complications and survival rate of inlays/onlays versus full coverage restorations as is depicted in the flow chart (Figure 2). The remaining 12 articles were excluded for different reasons and were not analysed further (Table 2).[64-75] Six out of the 9 studies included in this review were retrospective,[45-50] while the remaining 3 were prospective.[51-53] Four out of the 9 included studies provided data from records of patients who had been treated with either partial or full coverage restorations in private dental offices during a specific time period.[45-47,49] In 3 of the included studies, the treatment protocols were conducted in a university setting [48,51,52] while 2 of them provided data from patients who received treatment either at the authors' private offices or at a university clinic.[51,53]

Mean follow up periods varied significantly in the aforementioned studies, ranging from 1 to 52 years. The total number of restorations inspected also varied significantly in the reviewed studies, from 42 in the study of Reich et al[51] to 16 858 in the study of Sulaiman et al[49] In all studies included in this review restorations were clinically examined at follow-up appointments.

TABLE 2 Studies excluded from the systematic review

First author	Year	Study	Reason for exclusion
Belli et al	2015	Retrospective analysis	No details regarding the outcome
Della Bona et al	2008	Literature review	Literature Review
Chun-Li lin et al	2009	Prospective clinical trial	Endodontically treated tooth
Ploumaki et al	2013	Systematic review	Systematic Review
Wittneben et al	2009	Systematic review	Systematic review
Oilo et al	2014	Retrospective study	Only crowns
Guess et al	2009	Prospective clinical study	Only partial coverage restorations
Angeletaki F	2016	Systematic review -meta-analysis	Only partial coverage restorations
Roggendorf et al	2012	Prospective clinical study	No additional information regarding the survival rate of different restoration types. No inlays included in the study sample
Van Dijken et al	1999	Literature review	Literature review
Geurtsen et al	1999	Literature review	Literature review
Brodbeck UR	1997	Retrospective study	Author responded, but couldn't retrieve the article

TABLE 3 Random effects meta-analysis of survival rate (SR) according to the different types of restorations

Type of restoration	Number of studies	Q	df	P
Inlay	3	0.4949	2	0.7808
Onlay	6	0.1859	5	0.9993
Crown	9	1.1006	8	0.9975
Inlay-onlay	2	0.0012	1	0.9725
Random effects ANOVA				
Model	**df**	**Q**	**P**	**P (Random)***
Between	3	0.2424	0.9705	0.585
Within	16	1.7825	1.0000	
Total	19	2.0249	1.0000	

*P(Random): P value from randomisation test.

4.2 | Patient characteristics

All articles included in this systematic review reported on patients in need of either at least 2 of the compared study groups (inlays/onlays vs full coverage restorations) or all of them. None of the aforementioned publications reported any specific treatment protocol received by patients prior to their main prosthodontic therapy. Two of the studies [48,50] have reported on oral and periodontal health of the patients, as one of their inclusion criteria, while three [48,50,51] of them included patients with parafunctional activities in their study population. Four studies [45,47,49,52] did not mention the gender of the treated patients, while the remaining five [46,48,50,51,53] included patients of both sexes. The age of patients ranged from 18 to 91 years, with no reports of patients with systematic diseases.

4.3 | Outcome characteristics

The outcomes resulting from further examination and meta-analysis of the included studies are presented in detail in Tables 3, 4, 5, 6 and 7.

4.4 | Primary outcomes

4.4.1 | Survival rate

As mentioned above, survival rate of the restoration is described as the percentage of the restorations being in situ throughout a specific observation period. This period varied between the studies included in this systematic review. This fact, along with marked differences in treatment protocols adopted by the authors of the included studies, as well as the variability in case selection, made the drawing of any conclusion as to the superiority of 1 type of restoration over the other, difficult.

In 5 out of the 9 included studies inlays/onlays demonstrated a slightly better clinical behaviour over full coverage restorations regarding the survival and the complications rates.[45,46,48-50] It should be pointed that, the authors of those papers clarified that the differences between the inlays/onlays and full coverage restorations were not always statistically significant.

Heckland et al supported that the survival rate of inlays/onlays was 99.80%, while that of crowns was 98.40%.[45] The authors however, did not report on the main reasons of failure for both restoration groups.[45] In the study of Donovan et al inlays and onlays demonstrated a survival rate of 95.30% and 97.00%, respectively, whereas crowns presented a survival rate of 96.10%.[46] Excellent results for the 5-year follow-up have been documented by Beier et al showing a 97.40% survival rate for crowns, and 98.90% for both onlays and inlays.[48] The survival rates for the 10-year follow-up are 90.00%, 92.40% and 96.80% for crowns, onlays and inlays, respectively. However, for the 20-year follow-up the study of Beier et al demonstrated a 58.90% survival rate for crowns, as well as a 76.80% for inlays, respectively. That study also has showed that caries consisted the main reason for failure in all restoration types.[48] Sulaiman et al reported a 98.85% survival rate for crowns and a 98.99% for inlays/onlays. The most frequent complication was fracture of the restorative material.[49] The study of Fabbri et al demonstrated a survival rate of 93.5%-93.78% for ceramic onlays and 96.10%-98.10% for ceramic crowns.[50] Clinical complications concerning the crowns included mostly minor cohesive fractures of the veneering ceramic, followed by crown chippings, core failures and finally loss of retention. Monolithic onlays mostly failed due to minor fracture of the ceramic, followed by loss of retention.[50]

On the contrary, in the study of Kelly et al full gold (FGCs) and ceramometal (CMCs) crowns presented the longest survival rates, while cast onlays the lowest.[47] Both types of full coverage restorations demonstrated very similar survival rates for the first 5 years (95.40% for FGCs vs 93.60% for CMCs). A descending course of the survival rate over the years was also demonstrated. The overall survival rate percentage for cast onlays for the 5-year period was 72.70%.

A further analysis of the collected data revealed that the mean survival rate of inlays was 90.89% (95% CI: 0.66-0.95), while for onlays and crowns the mean survival rate was 93.50% (95% CI: 0.86-0.97) and 95.38% (95% CI: 0.89-0.98), respectively. For the fourth study group, consisting of both inlays and onlays, the survival rate was found to be 99.43% (95% CI: 0.99-1). The assessment of the 95% bootstrap CI did not reveal a statistically significant difference between the 4 groups, ie crowns, inlays, onlays, inlays/onlays. The latter group was formed as 2 studies [45,49] supplied collectively the results for inlays and onlays. However, a wide confidence interval presented by the group of inlays (95% CI: 0.66-0.95) was highlighted. A statistically significant difference was demonstrated between the survival rate of all

TABLE 4 Mean survival rate (SR) estimates according to the different types of restorations

Type of restoration	Number of studies	Mean SR	Bias Corrected 95% CI
Inlay	3	0.9089	0.6552-0.9491
Onlay	6	0.9350	0.8645-0.9676
Crown	9	0.9538	0.8871-0.9822
Inlay-onlay	2	0.9943	0.9899-0.9981
Total	20	0.9528	0.9115-0.9754

TABLE 5 Mean failure rate (FR) according to the different types of failures (biological/technical)

Type of failure	Number of studies	FR*	Bias corrected 95% CI	Q	df	P
B.Caries	3	0.1994	0.1351-0.3333	0.2107	2	0.9000
B.Endo	4	0.0805	0.0567-0.1379	0.0941	3	0.9925
B.Fracture	6	0.1134	0.0677-0.3157	2.4961	5	0.7771
B-sensitivity	2	0.0476	0.0270-0.2000	0.1318	1	0.71653
T.C.Fracture	5	0.5229	0.3467-0.7068	1.0927	4	0.8954
T.Chip	4	0.1151	0.0628-0.3738	1.0703	3	0.7843
T.Retention	2	0.1737	0.1429-0.2500	0.0327	1	0.8565

FR, failure rate.

TABLE 6 Random effects meta-analysis of survival rate (SR) according to the different types of study design (prospective/retrospective)

Class	Number of studies	Q	df	P
PRO	7	0.5987	6	0.99642
RE	13	0.8372	12	0.99999
Random effects ANOVA				
Model	**df**	**Q**	**P**	**P(Random)**
Between	1	0.5890	0.44282	0.028
Within	18	1.4359	1.00000	
Total	19	2.0249	1.00000	

PRO, Prospective study; RE, Retrospective study; *P* (Random), *P* value from randomisation test.

TABLE 7 Mean survival rate (SR) estimates according to the different types of study design (prospective/retrospective)

Class	#Studies	Survival rate	df	Bias corrected 95% CI
PRO	7	0.8470	6	0.7638-0.9334
RE	13	0.9655	12	0.9291-0.9816
Total	20	0.9528		0.9121-0.9755

restoration groups and the 2 different type of studies included in the analysis (prospective-retrospective).[76] A mean survival rate of 84.70% (95% CI: 0.76-0.93) for all restorations was noted in the prospective studies, while the mean survival rate for all restorations included in the retrospective studies was 96.55% (95% CI: 0.93 -0.98). Analysis of the studies with follow-up times greater than 100 months demonstrated a strong negative correlation between the survival rate and the follow-up time (Spearman's rho = −0.748, $P < 0.001$). (Figure 3)

4.5 | Secondary outcomes

4.5.1 | Type of failures

Four of the included studies provided data concerning the type of clinical complications related to the failure of each different type of restoration. In this systematic review, failures were grouped as either biological or technical.[77] Biological complications included caries, endodontic treatment, tooth and/or root fracture and hypersensitivity. Technical failures included ceramic fracture, crack, core failure, chipping, problems with marginal integrity and loss of retention.

Caries was referred as a reason of failure only by Beier et al who reported that caries accounted for 13.50% of the total failures of crowns, 33.30% of the inlays and 20.00% of the onlays. Only 2 studies referred to failures due to endodontic reasons.[48,50] Beier et al reported that endodontic reasons accounted for 5.41% of the total failures of crowns, 9.52% for inlays and 20.00% for onlays.[48] Fabbri et al's study demonstrated that endodontic reasons were responsible for 7.14% of the total failures for crowns, with no percentage given for inlays and onlays.[50]Root and/or tooth fracture accounted for 8.10% and 4.76% of the total failures for crowns and inlays, respectively, in the study of Beier et al[48] 7.14% for crowns in the study of Fabbri et al[50] 4.54% for onlays in the study of Reich et al[51] and 25.00% for crowns in the study of Barnes et al[52] Only Beier et al reported that from the pool of the total failures, 20.00% of onlays, and 2.70% for crowns developed hypersensitivity.[48]

Ceramic fracture, crack and core failure were reported as technical failures by 3 of the studies included in this systematic review.[48,50,52] On that issue Beier et al found that 64.86% of failures of crowns, 42.85% of those of inlays and 20.00% of onlays' failures were attributed to some kind of ceramic failure.[48] Fabbri et al[50] and Barnes et al[52] have demonstrated that 71.42% of the total failures of crowns, as well as of the only onlay [52] placed were due to ceramic fracture.

A further statistical analysis of the collected data demonstrated caries to be the main biological complication presented by all types of restorations, with a mean failure rate of 19.94% (95% CI: 0.14-0.33), followed by a root and/or tooth fracture incidence of 11.34% (95% CI: 0.068-0.32). Endodontic reasons exhibited the third higher failure percentage among the other biological complications with a failure rate of 8.05% (95% CI: 0.06-0.14). A 4.76% (95% CI: 0.03-0.20) rate for sensitivity was also recorded.

Ceramic fractures represented the most common technical complication, with a failure rate of 52.29% (95% CI: 0.35-0.71), followed by loss of retention with a 17.37% (95%CI: 0.14-0.25) rate. Chipping of the ceramic material accounted for 11.51% (95% CI: 0.06-0.37) of the total failures of all different types of restorations.

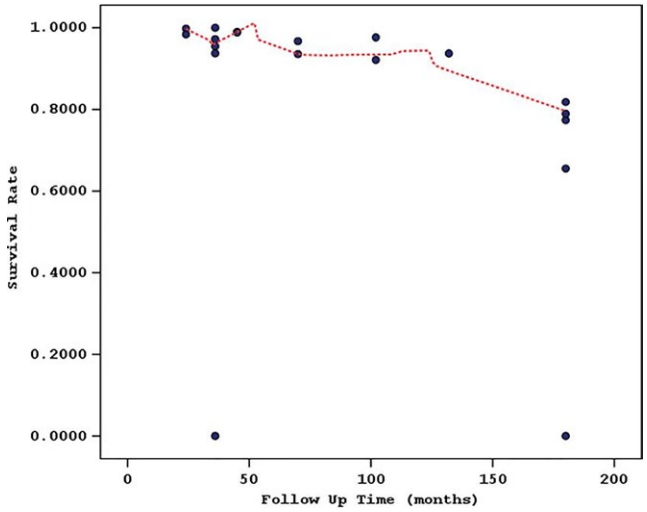

FIGURE 3 Correlation between SR and follow-up time (in mo), rho Spearmann (rho = −0.748, $P < 0.001$) [Colour figure can be viewed at wileyonlinelibrary.com]

The assessment of the 95% bootstrap CI could not establish an association between the kind of complications and different types of restorations. Nevertheless, a relatively high failure rate due to caries and ceramic fractures was noted. The latter was also recognised as the predominant cause of failure by several authors.[48,50,52]

4.5.2 | Evaluation criteria

All studies did not use the same criteria for restoration evaluation. Three criteria have been identified. These included the USPHS, the modified USPHS and the modified CDA. Donovan et al[46] and Reich et al[51] used the USPHS criterion, while the last one also used the modified USPHS criterion for the proximal contacts. The modified USPHS was also used by Barnes et al[52] and van Dijken et al.[53] Finally, Beier et al[48] and Fabbri et al[50] used the modified CDA. However, only Donovan et al and Beier et al specified which scale was considered as a failure (Charlie and Delta).[46,48] The rest of the authors did not report any additional information for each type of evaluation criteria.

4.5.3 | Inclusion criteria

Only 3 out of 9 studies reported on the necessary criteria a patient should fullfil in order to be included in the study. Beier et al[48] required periodontally healthy patients. Fabbri et al[50] set good oral hygiene, vital and endododontically treated teeth and natural dentition in the opposing arch, as their only requirements, while Reich et al[51] included only extensively damaged teeth.

4.5.4 | Parafunctional habits

Only 4 out of the 9 included studies commented on the parafunctional habits that the treated patients had. Specifically, van Dijken et al[53] mentioned that bruxers were included in their study, without giving any numbers. Reich et al[51] reported on an onlay fracture due to bruxing, without supplying any information regarding the total number of bruxers included in their study. The study of Fabbri et al[50] reported that 30.34% of the treated patients had parafunctional habits, without giving more information on that subject. Finally, Beier et al[48] cited the exact number of bruxers (35.09%) included in their study.

4.5.5 | Means of isolation

Only 2 studies [50,51] mentioned that rubber dam was used during the clinical procedures.

4.5.6 | Dropouts

Unfortunately, only 3 studies supplied data regarding the dropouts. One of those studies reported dropouts at restoration level, stating that 10.00% of the crowns, and 31.57% of the onlays could not be re-evaluated.[45] In contrast, the studies of Donovan et al. [46] and van Dijken et al[53] reported dropouts at patient level. In the first of these 2 studies 5.00% of the patients have not been re-evaluated, while in the second one 14.04% of patients did not come back for reassessment.

4.5.7 | Quality assessment

Considering the quality of evidence provided by the studies included in this systematic review, the overall quality of evidence is low as no randomised controlled trial (RCT), was identified for inclusion (Figure 4).

5 | DISCUSSION

The main purpose of this review was to identify clinical studies in which crowns and inlays/onlays were used to restore damaged teeth, and compare their biological and technical complications, as well as their survival rates. Moreover, possible outcome differences between the 2 different treatment modalities (crowns vs inlays/onlays) were also investigated. Therefore, a systematic search of published literature was organised and carried out in order to identify high-level evidence.

It was the intention of the authors this systematic review to be conducted in accordance with the guidelines of PRISMA[40] and the Cochrane Collaboration's tool for assessing risk of bias[62] in randomised trials. Nevertheless, a modification was considered necessary, as no RCT satisfying the inclusion criteria was found in the literature.

A total of 9 observational studies were included in the analysis, after a thorough electronic and hand search strategy were conducted. It should be mentioned, however, that a great variation both in the number of restorations evaluated and the follow-up periods was identified. The biggest number of restorations was evaluated by Sulaiman et al[49] who have reported on 16 858 units, while the longest evaluation period was accomplished by Donovan et al[46] who reported for a period of up to 52 years. As it is evident, patients in

the latter of these 2 studies were followed for different lengths of time. This is a common practice in cohort studies like this one, as not all patients enter the study at the same point in time. The follow-up and data collection start when the subject enters the study and finishes when any of the following happens first: (a) the study ends (b) they are recorded as a failure, (c) they cannot be contacted (lost to follow-up), (d) they have passed away.[78]

The restorative treatments examined in the studies included in this systematic review were performed in both males and females and in a very wide range of ages, covering the whole spectrum of adulthood. As it is known, both sex and age are probably the most confounding variables in medical/dental studies, as they are associated with exposures of interest, such as diet, muscular strength and oral hygiene.[79] Other factors contributing to the survival of dental restorations have also been identified by Chadwick et al and they include the type of the dentition, the site and the size of the restoration, the reason for restoration placement, the caries status, the socioeconomic status of the patient, the frequency of changing dentists, and restorations' deficiencies during the fabrication process.[80] Unfortunately, the influence that these variables may have on the final outcome is not discussed in any of the cohort studies included.

Differences in settings (universities vs private dental clinics), treatment protocols, experience, age and clinical skills of operators, periodontal factors, tooth history and extent of tooth destruction prior to restoration make the drawing of definitive conclusions very difficult.[27,28] However, it is encouraging that according to most authors, both treatment options present high survival rates for the first 5 years, exceeding 90%. Moreover, the differences between the 2 different types of restorations are not always statistically different. It should be mentioned at this point that, survival is defined as the number (or percentage) of restorations that remain in situ, with or without modification.[81] An interesting fact is that the study of Beier et al which has demonstrated that the survival rate for crowns and inlays after 20 years was 58.90%, and 76.80%, respectively.[48] A marked difference in survival can be noted among these 2 restorations. It should be mentioned however that, these results are quite satisfactory for the 20-year time period, especially if it is taken into account the high percentage of bruxer patients (35.09%) participating in that study. A systematic review on bruxism and prosthetic treatment by Johansson et al has shown that bruxism is associated with an increased rate of mechanical and technical complications.[82] Another important fact about the study of Beier et al is that zinc phosphate luting agent was used for the majority of the restorations.[48] A prospective clinical study [83] has shown that there are no statistically significant differences in the outcome of restorations luted with resin and zinc phosphate cements. However, zinc phosphate when compared with resin cements, demonstrates no chemical or micromechanical bonding, while it has lower compressive and tensile strengths, as well as high solubility in oral fluids.[84] The latter disadvantage of zinc phosphate cement may partially explain the fact that secondary caries was the main reason of biological complication in the study of Beier et al.[48] Besides biological, technical failures also determine the survival of the restorations. When single

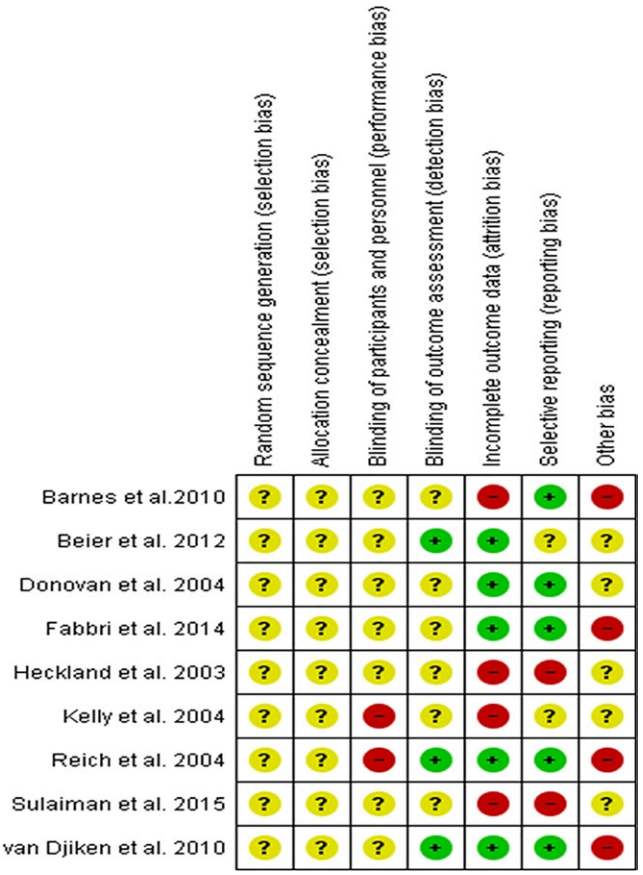

FIGURE 4 Risk of bias summary. Author's assessment about each risk of bias item for each included study. The question mark inside the circle indicates an unclear risk of bias, while the plus and minus inside the circle denote low and high risk of bias respectively. The first two domains accounting for selection bias are characterized as unclear, as there are no randomized/observational studies included in this review. The overall assessment of a study containing only plus is considered as "low-risk" of bias, whereas studies containing at least one minus or question mark are considered as "high-" or "unclear risk" of bias respectively [Colour figure can be viewed at wileyonlinelibrary.com]

restorations are examined these mainly include cracking, chipping and bulk fracture.[85] The studies of both Sulaiman et al and Fabbri et al have demonstrated very high survival rates, ranging from 93.50% to 98.99%.[49,50] In these 2 studies, the most frequent complications were not biological as those in the study of Beier et al.[48] On the contrary, some technical complications were encountered. These included cohesive factures and chippings. An interesting fact is that in the study of Fabbri et al layered crowns presented a higher survival rate (98.10%) than the monolithic ones (96.10%) [50] It should be mentioned however that, these rates are quite similar and probably not statistically significant different. Nevertheless, it should be emphasised that the literature suggests that monolithic crowns present better mechanical properties than the layered ones. Several studies have demonstrated that the flexural strength of veneering materials can range between 60 and 120 MPa, while the corresponding value for a core material exceeds 450 MPa.[86-88] Moreover,

a mismatch between the coefficients of thermal expansion of the veneering and the core material may cause stress fields throughout the restoration, resulting in chipping or bulk fracture. Unsupported porcelain, due to improper core design, can also be one of the reasons of fracture, as research has shown that restorations supported by anatomically correct cores presented smaller fatigue-caused chippings than cores with a flat design. Furthermore, restorations with anatomical cores could tolerate higher stresses than the non-anatomical ones.[89] Other parameters, including prepared tooth's axial wall height, thicknesses of core and veneering materials, cement thickness and modulus of elasticity, as well as loading conditions, may influence the restoration's longevity.[90,91] The study of Kelly et al has demonstrated that full coverage restorations, either metal ceramic or full gold, present a higher survival rate than cast onlays.[47] This is an interesting finding, as onlays are usually placed on teeth which are less damaged than those restored with a full coverage restoration. It should be mentioned however that the decision as to which type of restoration will be used is also a matter of experience, clinical judgement and skills.[80] Unfortunately, the biological and technical complications leading to failures have not been included in that article by the authors. Therefore, only assumptions can be made for that purpose. The fact that the preparation of an onlay is more technically demanding when compared with that of a full coverage restoration may be one reason.[9] The lower survival rate may also be attributed to the fact that onlays have a longer finishing line than the corresponding full coverage restorations. Therefore, there is a bigger chance for recurrent decay. Finally, it has been claimed that onlays are mechanically inferior when compared with full coverage restorations, due to their incomplete ring design.[9] A comparison between full gold, metal-ceramic and all-ceramic restorations cannot be performed from this study as the majority of the restorations were metal-ceramic (65.63%) followed by full gold (28.79%). All-ceramic restorations represented only 5.57%.

Different criteria for the evaluation of restorations have been adopted by the authors of the studies included in this systematic review. A common problem is that usually there is a perceptual and a judgemental variation among evaluators of different studies. Furthermore, the procedures used for evaluation and use of other supplemental aids vary. Therefore, a direct comparison of the results is almost impossible. Six out of the 9 included studies referred to the evaluation criteria used. These included both the USPHS and the CDA. The first one was developed by Cvar and Ryge in 1971, in order to be used for the clinical evaluation of dental restorative materials.[92] It was intended to be used by the United States Public Health Service (USPHS). The CDA system is a variation of the system proposed by Cvar and Ryge, and it has been adopted by the California Dental Association (CDA).[93] These criteria evaluate colour matching, anatomic contour, surface texture, cavosurface marginal discoloration, marginal integrity, secondary caries and gross fracture.[94] Both the USPHS and the CDA systems are based on an ordinal scale, and evaluate the restorations as "acceptable" or "not acceptable." For that reason, modified criteria have been developed, in order to complement the 2 original systems, for a better evaluation of the characteristics of indirect and direct restorations.[95,96]

Another important point, which is not addressed by several authors, is the inclusion criteria. Only 3 out of the 9 studies of this systematic review reported on this issue.[48,50,51] It should be mentioned however that, the authors of these 3 studies did not clearly define the inclusion criteria. Terms like good oral hygiene and extensively damaged teeth are used by the authors, with no further explanation. Nevertheless, inclusion criteria are very important if consistency of findings among similar studies is to be accomplished. Inclusion criteria have to have a good validity and reliability in order to assist minimising random error, misclassification of exposures and outcomes, selection bias and confounding factors. This last variable is very important in observational studies, as inclusion criteria can be used to control it, in the form of specification or restriction and matching. In this way imbalances between comparison groups are removed or homogenised.[97]

Although parafunctional habits and especially bruxism is considered as a major factor for tooth wear and prostheses failures, only 4 out of the 9 selected studies commented on this issue.[48,50,51,53] Of those, only 2 studies supplied enough details regarding the number of patients who were bruxers.[48,50] However, no information is supplied regarding the number of failing units in bruxers. As already mentioned in the results, only the study of Reich et al identified an onlay fracture due to bruxism.[51] Although a direct relationship between bruxism and technical or biological complications has not been established in the past, there are some studies which have noted a possible association between them.[98,99] Therefore, it would be beneficial if the authors of the selected studies had reported on incidences of failures possibly associated with bruxism. It has been discussed in the literature that probably metal and metal-ceramic restorations are the safest choices for patients with parafunctional habits.[100,101] Monolithic materials—either zirconia or lithium disilicate—which exhibit high flexural strength, can probably be used for those patients, as well.[102,103] The materials used in the studies selected for this systematic review included gold, metal-ceramic and all-ceramic. These studies were published between 2004 and 2015. Therefore, different types of ceramics (feldspathic, leucite reinforced, lithium disilicate) have been used by the authors. Moreover, ceramics are continuously improving, as a lot of research is being placed towards that direction. In a review on the performance of dental ceramics, Rekow et al have pointed out that not only the properties change, as the materials improve, but also the fabrication conditions may differ. In addition, the handling conditions during the clinical procedures may vary widely. All these parameters have as a result a difficulty in drawing conclusions or ensuring the equivalence of success even within a single class of ceramic.[104] Another parameter which is important and no information is given by the authors is that of the core material. An in vitro study has shown that full coverage ceramic restorations have a high probability of fracture if they are cemented on cores made of resin-modified glass-ionomer materials, as they lack rigidity and may present a hygroscopic expansion.[105]

The luting agents used in the selected studies included zinc phosphate, flowable composite resin, chemically cure and dual cure resin cements. Marked cement dissolution is seldom observed, as all luting agents comply with ADA or ISO standards. However, inadequate moisture control and presence of saliva during the cementation procedures

can adversely affect cements like zinc phosphate or glass ionomer, resulting in ineffective marginal seal and recurrent decay.[106,107] Although resin-based cements are not affected by moisture, their handling is also sensitive. If all precautions are taken these cements resist wear and solubility much better than conventional cements.[108] It should be mentioned however that, disintegration of luting agents may also start under restorations deformed by occlusal loading, leading to cement fracture after crack propagation.[109] Although gold cast and metal ceramic restorations can be luted with any cement, all ceramic restorations should be luted with resin cements, as literature has shown that acid etched all ceramic restorations cemented with resin composite present a significantly better survival function than those cemented with either glass ionomer or zinc phosphate cements. The same clinical study has shown that differences between all ceramic restorations luted with glass ionomer or zinc phosphate agents were not significant.[110]

As already mentioned in the results section all but 2 studies [46,49] provided information about the location of the restorations. Unfortunately, the authors of all papers did not provide information about the location of the restorations which failed. This is a very important issue, as the literature suggests that both biological and technical complications may be associated with the location of the restorations. A clinical study of 88 direct and indirect composite resin restorations followed for a period of 2 years has shown that molars present significantly higher postoperative symptoms than premolars.[111] Furthermore, technical complications as porcelain chippings and bulk fractures are noticed more often in posterior than in anterior restorations. This can be attributed to both the greater masticatory loads present in the posterior regions (especially in bruxer patients) and the lateral forces on balancing cusps.[109] It has been demonstrated in the past that the lingual cusps of mandibular molars exhibited the highest frequency of fractures.[112]

Only one prospective [53] and 2 retrospective studies [45,46] reported dropout patients. Follow-up of patients is essential in order to draw safe conclusions from a clinical study. It is important to include in the study a mechanism that accomplishes the lowest possible dropout rate. Nevertheless, as the length of the study increases so do the chances of dropouts. It should be mentioned however that, any systematic differences which are related to the outcome or exposure to identified risk factors, between patients who dropped out and those still in the study, are of a greater concern than the dropouts. The authors of cohort studies should include in the analysis of data a comparison of risk factors between subjects who remain in the study and those who have dropped out. The reliability of a clinical study may be questioned if loss to follow-up is ignored.[113]

6 | CONCLUSIONS

Within the limitations of this systematic review and analysis of studies, the following conclusions can be drawn:

- The 5-year survival rate for crowns and inlays/onlays is very high, exceeding 90%.
- Recurrent decay, endodontic reasons and tooth fractures were the most frequent biologic complications.
- Ceramic fractures and core failures were the most frequent prosthetic complications.
- The overall quality of evidence of the 9 studies was low. Due to the heterogeneity of the included studies no meaningful comparison could be made between types or restoration of materials.

ACKNOWLEDGMENTS

No ethical approval was obtained as this research study did not involve participation of any humans or animals. No funding was obtained from any institution or agency. This work was supported solely by its authors. The authors have stated explicitly that there are no conflicts of interest in connection with this article.

ORCID

Konstantinos Michalakis http://orcid.org/0000-0001-5891-4823

REFERENCES

1. McCaul LK, Jenkins WM, Kay EJ. The reasons for extraction of permanent teeth in Scotland: a 15-year follow-up study. *Br Dent J*. 2004;196:639-643.
2. Nascimento MM, Gordan VV, Qvist V, et al. Restoration of noncarious tooth defects by dentists in The Dental Practice-Based Research Network. *J Am Dent Assoc*. 2011;142(12):1368-1375.
3. Bhaskar SN. *Synopsis of Oral Pathology*. St. Louis, MO: C.V. Mosby; 1986:99-137.
4. Murray CJ, Barber RM, Foreman KJ, et al. Global, regional, and national disability-adjusted life years (DALYs) for 306 diseases and injuries and healthy life expectancy (HALE) for 188 countries 1990–2013: quantifying the epidemiological transition. *Lancet*. 2015;386(10009):2145-2191.
5. Steele JG, Treasure E, Pitts NB, Morris J, Bradnock G. Total tooth loss in the United Kingdom in 1998 and implications for the future. *Br Dent J*. 2000;189:598-603.
6. Leinfelder KF, Yarnell G. Occlusion and restorative materials. *Dent Clin North Am*. 1995;39(2):355-361.
7. Qualtrough AJE, Satterthwaite JD, Morrow LA, Brunton PA. *Principles of Operative Dentistry*. Oxford, UK: Blackwell Munksgaard; 2005:27-50, 107-128.
8. Shillingburg Jr HT, Jacobi R, Brackett SE. *Fundamentals of Tooth Preparation for Cast Metal and Porcelain Restorations*. Chicago, IL: Quintessence; 1987.
9. Wiskott AHW. *Fixed Prosthodontics. Principles and Clinics*. London, UK: Quintessence; 2011:389-440.
10. Yip KH, Smales RJ, Kaidonis JA. Differential wear of teeth and restorative materials: clinical implications. *Int J Prosthodont*. 2004;17:350-356.
11. Manhart J, Chen H, Hamm G, Hickel R. Review of the clinical survival of direct and indirect restorations in posterior teeth of the permanent dentition. *Oper Dent*. 2004;29:481-508.
12. Goodacre CJ, Spolnik KJ. The prosthodontic management of endodontically treated teeth: a literature review. Part I. Success and failure data, treatment concepts. *J Prosthodont*. 1994;3:243-250.

13. Wassel RW, Walls AN, Steele JG. Crowns and extra-coronal restorations: materials selection. *Br Dent J*. 2002;89:199-211.
14. Sailer I, Gottner J, Känel S, Hämmerle CH. Randomized controlled clinical trial of zirconia-ceramic and metal-ceramic posterior fixed dental prostheses: a 3-year follow-up. *Int J Prosthodont*. 2009;2:553-560.
15. Silva NR, Bonfante EA, Zavanelli RA, Thompson VP, Ferencz JL, Coelho PL. Reliability of metalloceramic and zirconia-based ceramic crowns. *J Dent Res*. 2010;89:1051-1056.
16. Tucker RV. Why gold castings are excellent restorations. *Oper Dent*. 2008;33:113-115.
17. Brecker SC. Porcelain baked to gold – a new medium in prosthodontics. *J Prosthet Dent*. 1956;6:801-810.
18. Kelly JR, Nishimura I, Campbell SD. Ceramics in dentistry: historical roots and current perspectives. *J Prosthet Dent*. 1996;75:18-32.
19. Asgar K. Casting metals in dentistry: past-present-future. *Adv Dent Res*. 1998;2:33-43.
20. Sailer I, Makarov NA, Thoma DS, Zwahlen M, Pjetursson BE. All-ceramic or metal-ceramic tooth-supported fixed dental prostheses (FDPs)? A systematic review of the survival and complication rates. Part I: Single crowns (SCs). *Dent Mater*. 2015;31(6):603-623.
21. Kelly JR, Benetti P. Ceramic materials in dentistry: historical evolution and current practice. *Aust Dent J*. 2011;56(1):84-96.
22. Giordano II RA, Pelletier L, Campbell S, Pober R. Flexural strength of an infused ceramic, glass ceramic, and feldspathic porcelain. *J Prosthet Dent*. 1995;73:411-418.
23. Quinn JB, Quinn GD, Sundar V. Fracture toughness of veneering ceramics for fused to metal (PFM) and zirconia dental restorative materials. *J Res Natl Inst Stand Technol*. 2010;115:343-352.
24. Shenoy A, Shenoy N. Dental ceramics: an update. *J Conserv Dent*. 2010;13:195-203.
25. Holloway JA, Miller RB. The effect of core translucency on the aesthetics of all-ceramic restorations. *Pract Periodontics Aesthet Dent*. 1997;9:567-574.
26. Rekow ED, Silva NR, Coelho PG, Zhang Y, Guess P, Thompson VP. Performance of dental ceramics: challenges for improvements. *J Dent Res*. 2011;90:937-952.
27. Malament KA, Socransky SS. Survival of Dicor glass-ceramic dental restorations over 20 years. Part IV: The effects of combinations of variables. *Int J Prosthodont*. 2010;23:134-140.
28. Burke FJ, Lucarotti PS. Ten-year outcome of crowns placed within the General Dental Services in England and Wales. *J Dent*. 2009;37(1):12-24.
29. Pjetursson BE, Sailer I, Zwällen M, Hämmerle CH. A systematic review of the survival and complication rates of all-ceramic and metal-ceramic reconstructions after an observation period of at least 3 years. Part I: Single crowns. *Clin Oral Implants Res*. 2007;18(3):73-85.
30. Guazzato M, Albakry M, Ringer SP, Swain MV. Strength, fracture toughness and microstructure of a selection of all-ceramic materials. Part II. Zirconia-based dental ceramics. *Dent Mater*. 2004;20(5):449-456.
31. Cehreli MC, Kokat AM, Akca K. CAD/CAM Zirconia vs. slip-cast glass-infiltrated Alumina/Zirconia all-ceramic crowns: 2-years results of a randomized controlled clinical trial. *J Appl Oral Sci*. 2009;17(1):49-55.
32. Ortorp A, Kihl ML, Carlsson GE. A 3-year retrospective and clinical follow-up study of zirconia single crowns performed in a private practice. *J Dent*. 2009;37(9):731-736.
33. Lameira DP, Buarque e Silva WA, Andrade e Silva F, De Souza GM. Fracture strength of aged monolithic and bilayered zirconia-based crowns. *Biomed Res Int*. 2015;2015:7-14.
34. Jang GW, Kim HS, Choe HC, Son MK. Fracture strength and mechanism of dental ceramic crown with zirconia thickness. *Procedia Eng*. 2011;10:1556-1560.
35. Sulaiman TA, Delgado AJ, Donovan TE. Survival rate of lithium disilicate restorations at 4 years: a retrospective study. *J Prosthet Dent*. 2015;114(3):364-366.
36. Studer SP, Wettstein F, Lehner C, Zullo TG, Schärer P. Long-term survival estimates of cast gold inlays and onlays with their analysis of failures. *J Oral Rehabil*. 2000;27(6):461-472.
37. Mulica A, Svendsenb G, Kopperuda SE. A retrospective clinical study on the longevity of posterior Class II cast gold inlays/onlays. *J Dent*. 2018;70:46-50.
38. Schulte AG, Vöckler A, Reinhardt R. Longevity of ceramic inlays and onlays luted with a solely light-curing composite resin. *J Dent*. 2005;33(5):433-442.
39. Morimoto S, Rebello de Sampaio FB, Braga MM, Sesma N, Özcan M. Survival rate of resin and ceramic inlays, onlays and overlays: a systematic review and meta-analysis. *J Dent Res*. 2016;95(9):985-994.
40. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. *BMJ*. 2009;21(339):b2700.
41. Conrad HJ, Seong WJ, Pesun IJ. Current ceramic materials and systems with clinical recommendations: a systematic review. *J Prosthet Dent*. 2007;98(5):389-404.
42. Armitage P, Berry G. *Statistical Methods in Medical Research*, 3rd edn. Oxford, UK: Blackwell Scientific; 1994.
43. Richards D. Grading–levels of evidence. *Evid Based Dent*. 2009;10(1):24-25.
44. Rosen E, Nemcovsky CE, Tsesis I. *Evidence-Based Decision Making in Dentistry*. Berlin, Germany: Springer; 2017:37-38.
45. Hekland H, Riise T, Berg E. Remakes of Colorlogic and IPS Empress ceramic restorations in general practice. *Int J Prosthodont*. 2003;16(6):621-625.
46. Donovan T, Simonsen RJ, Guertin G, Tucker RV. Retrospective clinical evaluation of 1,314 cast gold restorations in service from 1 to 52 years. *J Esthet Restor Dent*. 2004;16(3):194-204.
47. Kelly PG, Smales RJ. Long-term cost-effectiveness of single indirect restorations in selected dental practices. *Br Dent J*. 2004;196(10):639-643.
48. Beier US, Kapferer I, Dumfahrt H. Clinical long-term evaluation and failure characteristics of 1335 all-ceramic restorations. *Int J Prosthodont*. 2012;25(1):70-78.
49. Sulaiman TA, Delgado AJ, Donovan TE. Survival rate of lithium disilicate restorations at 4 years: a retrospective study. *J Prosthet Dent*. 2015;114(3):364-366.
50. Fabbri G, Zarone F, Dellificorelli G, et al. Clinical evaluation of 860 anterior and posterior lithium disilicate restorations: retrospective study with a mean follow-up of 3 years and a maximum observational period of 6 years. *Int J Periodontics Restorative Dent*. 2014;34(2):165-177.
51. Reich SM, Wichmann M, Rinne H, Shortall A. Clinical performance of large, all-ceramic CAD/CAM-generated restorations after three years: a pilot study. *J Am Dent Assoc*. 2004;135(5):605-612.
52. Barnes D, Gingell JC, George D, Adachi E, Jefferies S, Sundar VV. Clinical evaluation of an all-ceramic restorative system: a 36-month clinical evaluation. *Am J Dent*. 2010;23(2):87-92.
53. Van Dijken JW, Hasselrot L. A prospective 15-year evaluation of extensive dentin-enamel-bonded pressed ceramic coverages. *Dent Mater*. 2010;26(9):929-939.
54. Neyeloff J, Fuchs S, Moreira L. Meta-analyses and Forest plots using a Microsoft Excel spreadsheet: step-by-step guide focusing on descriptive data analysis. *BMC Res Notes*. 2012;5:52.
55. Borenstein MH, Higgins L, Rothstein JHR. *Introduction to Meta-analysis*. Chichester, UK: Wiley; 2009:10.
56. Gurevitch J, Hedges LV. Statistical issues in ecological meta-analyses. *Ecology*. 1999;80(4):1142-1149.

57. Theodoridis C, Grigoriadis A, Menexes G, Vouros I. Outcomes of implant therapy in patients with a history of aggressive periodontitis. A systematic review and meta-analysis. *Clin Oral Investig*. 2017;21(2):485-503.
58. Adams DC, Gurevitch J, Rosenberg MS. Resampling tests for meta-analysis of ecological data. *Ecology*. 1997;78(4):1277-1283.
59. Veresoglou SD, Menexes G, Rillig MC. Do arbuscular mycorrhizal fungi affect the allometric partition of host plant biomass to shoots and roots? A meta-analysis of studies from 1990 to 2010. *Mycorrhiza*. 2012;22(3):227-235.
60. Rosenberg MS, Adams DC, Gurevitch J. *MetaWin: Statistical Software for Meta-analysis*. Sunderland, MA: Sinauer Associates; 2000.
61. Jacoby WG. Loess: A nonparametric, graphical tool for depicting relationships between variables. *Elect Stud*. 2000;19:577-613.
62. Higgins JP, Altman DG, Sterne AC. Assessing risk of bias in included studies. In: *Cochrane Handbook for Systematic Reviews of Interventions Version, 5.1.0*. Chichester, UK: Wiley. Available from www.cochrane-handbook.org.
63. Gkantidis N, Mistakidis I, Kouskoura T, Pandis N. Effectiveness of non-conventional methods for accelerated orthodontic tooth movement: a systematic review and meta-analysis. *J Dent*. 2014;42:1300-1319.
64. Brodbeck UR. Six years of clinical experience with an all-ceramic system. *Signature*. 1997;4(3):6-13.
65. Geurtsen W, García-Godoy F. Bonded restorations for the prevention and treatment of the cracked-tooth syndrome. *Am J Dent*. 1999;12(6):266-270.
66. Van Dijken JW. All-ceramic restorations: classification and clinical evaluations. *Compend Contin Educ Dent*. 1999;20(12):1115-1124.
67. Della Bona A, Kelly JR. The clinical success of all-ceramic restorations. *J Am Dent Assoc*. 2008;139:8S-13S.
68. Guess PC, Strub JR, Steinhart N, Wolkewitz M, Stappert CF. All-ceramic partial coverage restorations–midterm results of a 5-year prospective clinical split-mouth study. *J Dent*. 2009;37(8):627-637.
69. Wittneben JG, Wright RF, Weber HP, Gallucci GO. A systematic review of the clinical performance of CAD/CAM single-tooth restorations. *Int J Prosthodont*. 2009;22(5):466-471.
70. Lin CL, Chang YH, Pai CA. Evaluation of failure risks in ceramic restorations for endodontically treated premolar with MOD preparation. *Dent Mater*. 2011;27(5):431-438.
71. Roggendorf Mattias J, Kunzi B, Ebert J, Roggendorf HC, Frankenberger R, Reich SM. Seven-year clinical performance of CEREC-2 all-ceramic CAD/CAM restorations placed within deeply destroyed teeth. *Clin Oral Investig*. 2012;16(5):1413-1424.
72. Ploumaki A, Bilkhair A, Tuna T, Stampf S, Strub JR. Success rates of prosthetic restorations on endodontically treated teeth; a systematic review after 6 years. *J Oral Rehabil*. 2013;40(8):618-630.
73. Oilo M, Hardang AD, Ulsund AH, Gjerdet NR. Fractographic features of glass-ceramic and zirconia-based dental restorations fractured during clinical function. *Eur J Oral Sci*. 2014;122(3):238-244.
74. Belli R, Petschelt A, Hofner B, Hajtó J, Scherrer SS, Lohbauer U. Fracture rates and lifetime estimations of CAD/CAM all-ceramic restorations. *J Dent Res*. 2015;95(1):67-73.
75. Angeletaki F, Gkogkos A, Papazoglou E, Kloukos D. Direct versus indirect inlay/onlay composite restorations in posterior teeth. A systematic review and meta-analysis. *J Dent*. 2016;53:12-21.
76. Campbell MJ, Machin D, Walters SJ. *Medical Statistics: A Textbook for the Health Sciences*, 4th edn. Chichester, UK: Wiley; 1999:217-240.
77. Smith B, Howe LC. *Planning and Making Crowns and Bridges*, 4th edn. London, UK: Informa Healthcare; 2006:297-317.
78. Hackshaw A, Paul E, Davenport E. *Evidence-Based Dentistry. An Introduction*. Oxford, UK: Blackwell Publishing; 2007:119-121.
79. Richards D, Clarkson J, Matthews D, Niederman R. *Evidence-Based Dentistry: Managing Information for Better Practice*. London, UK: Quintessence; 2008:80-82.
80. Chadwick B, Treasure E, Dummer P, et al. Challenges with studies investigating longevity of dental restorations-a critique of a systematic review. *J Dent*. 2001;29(3):155-161.
81. Sailer I, Pjetursson BE, Zwalen M, Hammerle CH. A systematic review of the survival and complication rates of all-ceramic and metal-ceramic reconstructions after an observation period of at least 3 years. Part II: Fixed dental prostheses. *Clin Oral Implants Res*. 2007;18(3):86-96.
82. Johansson A, Omar R, Carlsson GE. Bruxism and prosthetic treatment: a critical review. *J Prosthodont Res*. 2011;55(3):127-136.
83. Behr M, Rosentritt M, Wimmer J, et al. Self-adhesive resin cement versus zinc phosphate luting material: a prospective clinical trial begun 2003. *Dent Mater*. 2009;25(5):601-604.
84. Ladha K, Verma M. Conventional and contemporary luting cements: an overview. *J Indian Prosthodont Soc*. 2010;10(2):79-88.
85. Anusavice KJ. Standardizing failure, success and survival decisions in clinical studies of ceramic and metal-ceramic fixed dental prostheses. *Dent Mater*. 2012;28(1):102-111.
86. Fischer J, Stawarczyk B, Hämmerle CH. Flexural strength of veneering ceramics for zirconia. *J Dent*. 2008;36(5):316-321.
87. Thompson VP, Rekow ED. Dental ceramics. In: Kokubo T, ed. *Bioceramics and Their Clinical Applications*. London, UK: CRC Press; 2008:518-547.
88. Bottino MA, Salazar-Marocho SM, Leite FP, Vasquez VC, Valandro LF. Flexural strength of glass-infiltrated zirconia/alumina-based ceramics and feldspathic veneering porcelains. *J Prosthodont*. 2009;18(5):417-420.
89. Lorenzoni FC, Martins LM, Silva NR, et al. Fatigue life and failure modes of crown systems with a modified framework design. *J Dent*. 2010;38(8):626-634.
90. Rafferty BT, Bonfante EA, Janal MN, et al. Biomechanical evaluation of an anatomically correct all-ceramic tooth-crown system configuration: core layer multivariate analysis incorporating clinically relevant variables. *J Biomech Eng*. 2010;132(5):051001-051006.
91. Rafferty BT, Janal MN, Zavanelli RA, et al. Design features of a three-dimensional molar crown and related maximum principal stress. A finite element model study. *Dent Mater*. 2010;26(2):156-163.
92. Cvar JF, Ryge G. *Criteria for the Clinical Evaluation of Dental Restorative Materials*. San Francisco, CA: United States Dental Health Center; 1971:7.
93. California Dental Association. *Guidelines for the Assessment of Clinical Quality and Professional Performance*, 3rd edn. Sacramento, CA: California Dental Association; 1995.
94. Barnes DM, Blank LW, Gingell JC, Gilner PP. A clinical evaluation of a resin-modified glass ionomer restorative material. *J Am Dent Assoc*. 1995;126(9):1245-1253.
95. Van Dijken JW. A clinical evaluation of anterior conventional, microfiller, and hybrid composite resin fillings. A 6-year follow-up study. *Acta Odontol Scand*. 1986;44(6):357-367.
96. Allander L, Birkhed D, Bratthall D. Quality evaluation of anterior restorations in private practice. *Swed Dent J*. 1989;13(4):141-150.
97. Velasco E, Salkind NJ, eds. *Encyclopedia of Research Design*. Thousand Oaks, CA: Sage Publications; 2012:589-591.
98. Brägger U, Aeschlimann S, Bürgin W, Hämmerle CH, Lang NP. Biological and technical complications and failures with fixed partial dentures (FPD) on implants and teeth after four to five years of function. *Clin Oral Implants Res*. 2001;12(1):26-34.
99. Eliasson A, Arnelund CF, Johansson A. A clinical evaluation of cobalt-chromium metal –ceramic fixed partial dentures and crowns: a three- to seven-year retrospective study. *J Prosthet Dent*. 2007;98(1):6-16.

100. Dahl B, Øilo G. *Wear of Teeth and Restorative Materials. Prosthodontics. Principles and Management Strategies*. London, UK: Mosby-Wolfe; 1996:187-200.
101. Johansson A, Omar R, Carlsson GE. Bruxism and prosthetic treatment: a critical review. *J Prosthodont Res*. 2011;55(3):127-136.
102. Örtrop A, Kihl ML, Carlsson GE. A 3-year retrospective and clinical follow-up study of zirconia single crowns performed in a private practice. *J Dent*. 2009;37(9):731-736.
103. Yu T, Wang F, Liu Y, Wu T, Deng Z, Chen J. Fracture behaviors of monolithic lithium disilicate ceramic crowns with different thicknesses. *RSC Adv*. 2017;7(41):25542-25548.
104. Rekow ED, Silva NR, Coelho PG, Zhang Y, Guess P, Thompson VP. Performance of dental ceramics: challenges for improvements. *J Dent Res*. 2011;90(8):937-952.
105. Sindel J, Frankenberger R, Krämer N, Petschelt A. Crack formation of all-ceramic crowns dependent on different core build-up and luting materials. *J Dent*. 1999;27(3):175-181.
106. Jacobs MS, Windeler AS. An investigation of dental luting cement solubilty as a function of the marginal gap. *J Prosthet Dent*. 1991;65(3):436-442.
107. Forsten L, Mount GJ, Knight G. Observations in Australia of the use of glass ionomer cement restorative material. *Aust Dent J*. 1994;39(6):339-343.
108. Zuellig-Singer R, Bryant RW. Three-year evaluation of computer-machined ceramic inlays: influence of luting agent. *Quintessence Int*. 1998;29(9):573-582.
109. Jokstad A, Bayne S, Blunck U, Tyas M, Wilson N. Quality of dental restorations. FDI Commission Project 2-95. *Int Dent J*. 2001;51(3):117-158.
110. Malament KA, Socransky SS. Survival of Dicor glass-ceramic dental restorations over 16 years. Part III: effect of luting agent and tooth or tooth-substitute core structure. *J Prosthet Dent*. 2001;86(5):511-519.
111. Scheibenbogen-Fuchsbrunner A, Manhart J, Kremers L, Kunzelmann KH, Hickel R. Two-year clinical evaluation of direct and indirect composite restorations in posterior teeth. *J Prosthet Dent*. 1999;82(4):391-397.
112. Eakle WS, Maxwell EH, Braly BV. Fractures of posterior teeth in adults. *J Am Dent Assoc*. 1986;112(2):215-218.
113. Levin KA. Study design IV: Cohort studies. *Evid Based Dent*. 2006;7(2):51-52.

How to cite this article: Vagropoulou GI, Klifopoulou GL, Vlahou SG, Hirayama H, Michalakis K. Complications and survival rates of inlays and onlays vs complete coverage restorations: A systematic review and analysis of studies. *J Oral Rehabil*. 2018;45:903–920. https://doi.org/10.1111/joor.12695