

## Review Article

# Comparative evaluation of clinical performance of ceramic and resin inlays, onlays, and overlays: A systematic review and meta analysis

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## Abstract

**Background:** Advances in adhesive technologies and escalation in esthetic demands have increased indications for tooth-colored, partial coverage restorations. Recently, material knowledge has evolved, new materials have been developed, and no systematic review has answered the question posed by practitioners: Is the clinical efficacy of resin or ceramic better, for inlay, onlay, and overlay in the long run?

**Aim:** The aim of this systematic review and meta-analysis was to evaluate the clinical performance of ceramic and resin inlays, onlays, and overlays and to identify the complication types associated with the main clinical outcomes.

**Materials and Methods:** Two reviewers (VN and AJ) searched PubMed, Embase, and Cochrane Central registry of controlled trials for published articles between 1983 and 2020 conforming to Preferred Reporting Items for Systematic Reviews and Meta-analyses guidelines for systematic reviews. Only clinical studies which met the following criteria were included (1) studies regarding ceramic and resin inlays, onlays, and overlays were included; (2) randomized controlled trials, retrospective or prospective studies conducted in humans; (3) studies with a dropout rate <50% 4) studies with a follow-up higher than 5 years.

**Results:** Of 1718 articles, 21 articles were selected. At 5 years, the estimated survival rates for resin ( $n = 129$ ) was 86%, feldspathic porcelain ( $n = 1048$ ) was 90%, and glass ceramic ( $n = 2218$ ) was 92%; at 10 years, the survival of resin was 75% ( $n = 115$ ), feldspathic porcelain was 91% ( $n = 1829$ ), and glass ceramic was 89% ( $n = 1075$ ).

**Conclusion:** The meta-regression indicated that ceramic partial coverage restorations (feldspathic porcelain and glass-ceramic) outperformed resin partial coverage restorations both at 5-year and 10-year follow-up. When compared between ceramic types, glass ceramics outperformed feldspathic porcelain at 5 years' follow-up and feldspathic porcelain outperformed glass ceramics at 10 years' follow-up. The failures were mostly due to fractures (6.2%), endodontic problems (3%), secondary caries (1.7%), and debonding which was 0.9%.

**Keywords:** Ceramics; composite resin; dental porcelain; dental restoration failure; dental restoration failure glass ceramics; longevity

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## INTRODUCTION

As with the advancements in the adhesive technologies and escalation in esthetic demands, the indications for tooth-colored, partial coverage restorations have drastically increased. Partial indirect restorations classified as inlays (without covering the cusps), onlays

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(covering at least 1 cusp), and overlays (covering all cusps)<sup>[1]</sup> enable conservation of the remaining dental structure, also helping in the reinforcement of a tooth compromised by caries or fractures.<sup>[2]</sup>

Currently, for the fabrication of indirect partial restorations, numerous resin or ceramic materials are present<sup>[3]</sup> and for their application in the posterior teeth, mechanical strength is of great value. Composites can be fabricated using chemical, heat, photo polymerization methods, or milling procedures from prefabricated computer-aided design/computer-aided manufacturing (CAD/CAM) blocks.<sup>[3]</sup>

Partial-coverage restorations are also made of feldspathic porcelain, glass, or crystalline ceramics. Feldspathic porcelain and glass-ceramic are available in powder (stratification) or blocks (CAD/CAM) and contain a vitreous and crystalline phase, in which a glassy matrix could be etched.<sup>[4,5]</sup>

Previous systematic reviews on the clinical survival of ceramic and resin inlays, onlays, and overlays were indecisive as it was not viable to perform a meta-analysis based on the chosen sample.<sup>[5,6]</sup> In a similar review of ceramic inlays, onlays, and overlays versus resin-based materials,<sup>[6]</sup> they concluded that there is little evidence to advocate the use of one material over the other or even the use of these materials over gold. Also, a recent systematic review and meta-analysis<sup>[7]</sup> could not perform a meta-analysis on the survival rate of resin indirect restoration.

Finally, material knowledge has evolved, new materials are developed, and no systematic review has answered the question posed by practitioners: Is the clinical efficacy of composite or ceramic better, for inlay and onlay and overlay in the long run? We aimed to perform a systematic review of published reports of clinical studies to evaluate the survival rate of resin and ceramic inlays, onlays, and overlays and to identify the types of complications associated with the main clinical outcomes.

## MATERIALS AND METHODS

This review is reported following the PRISMA guidelines with a Prospero Registration number: CRD42021256285.

### Information source

Articles describing survival of resin and ceramic inlay, onlay, and overlay restorations that were published between 1983 and December 2020 were selected for search in MEDLINE (PubMed), Cochrane Central Register of Controlled Trials (Central), and EMBASE databases. References of articles included were checked manually.

Adhesive procedures for ceramics were first standardized using hydrofluoric acid and silanization in the year 1983. So, we began our search from 1983.<sup>[8,9]</sup>

### Search strategy

PICOS question:-

(Population (P), Intervention (I), Comparison ©, Outcomes and Study Design (O), Study type (S)) defined the search strategy, where

P = Patients who had received resin or ceramic inlays, onlays and overlays;

I = Inlays, onlays and overlays that were made of resin or ceramic;

C = Resin inlays, onlays, overlays vs Ceramic inlays, onlays, overlays;

O = Survival rate;

S = Randomized controlled clinical trials (RCT) as well as clinical follow-up studies.

We used the following search terms, mesh terms, and their combinations for the search in medline: Inlay OR onlay OR overlay OR coverage AND porcelain OR ceram OR resin OR ceromer OR CAD/CAM) OR CEREC AND clinical evaluation OR clinical trial OR longevity OR success OR failure OR survival rate OR clinical performance OR follow up study OR clinical study OR comparative study.

For the search in EMBASE, the following terms were used: “ceramics” OR “porcelain” OR “porcelain tooth” OR “resin” OR “ceromer” AND (“dental inlay” OR “inlay” OR “onlay” OR “overlay”) AND (“clinical trial” OR “clinical study” OR “intervention study” OR “prospective study” OR “retrospective study” OR “follow up”) AND (1983–2020).

As for the search in “Central,” the search terms were as follows: (inlay or onlay or overlay) and (ceramic or resin) and (dental or tooth or teeth) and (clinical and trial or clinical).

## ELIGIBILITY CRITERIA AND STUDY SELECTION

For the inclusion criteria, all titles and abstracts of the studies selected were evaluated:

1. Studies associated with resin and ceramic inlays, onlays, and overlays
2. With clinical follow-up (retrospective or prospective) or randomized controlled trials (RCT), conducted in posterior teeth in humans

- Articles with missing abstract or abstracts with an insufficient description for enabling decision were included for our complete evaluation.

Eligibility decided after evaluation of the complete text was consistent with the previously defined exclusion criteria:

- Articles with missing description of the procedure, or which had uncommon preparations performed such as splinting, bridge abutments, occlusal coverage of posterior teeth without preparation, uncommon bonding procedures, restorations or implant abutments including metal
- Case reports
- Systematic or Literature review, interviews, protocols, *in vitro* studies
- Studies that were conducted in isolated groups (hypoplasia, bruxism, others)
- Studies including the same sample (the recent most and/or almost complete were considered)
- Studies that did not have survival analysis and had incomplete data for analysis
- Dropout that were higher than 50% and
- Follow-up time which was shorter than 5 years.

Two calibrated reviewers (VN, AJ) gathered the data from chosen papers onto structured tables. Between examiners, the Cohen's Kappa values ranged from 0.8 to 0.9, for the stages of inclusion and eligibility respectively. Discrepancies were resolved through consensus and a third examiner (BN) was consulted. The risk of bias in the studies included was assessed by two calibrated examiners (VN, AJ) using quality assessment.<sup>[10,11]</sup>

## Measures and statistical analysis

The data from the studies was collected and entered into MS Excel 2013. Data collected from the full-text articles. The data was described using appropriate descriptive statistical analysis.

Heterogeneity among the studies was evaluated using the Cochran Q test. The survival estimates were extracted from the studies and in case the study did not show standard deviation or a variance, analysis of the number of failures and censorship in the follow-up duration were used to calculate the survival rate.

The inverse variance method was performed with the DerSimonian–Laird estimator for the  $I^2$  value. Clopper–Pearson method was used to calculate the individual confidence intervals (CIs) of the studies from transformed data using StatsDirect Statistical Software Package (v 3.35).

A meta-analysis was performed of the survival rates for the overall restorations which had intervals of 5 years and 10 years. Later, meta-analysis of both resin group for survival rates for 5 years and 10 years as well as ceramic

group (glass ceramic and feldspathic porcelain) for 5 year and 10 y was also done. Also, analysis of survival rate for each ceramic type (glass-ceramics vs. feldspathic porcelain) in the subgroups was then performed. Considering the heterogeneity, a Random-effects model was used. Appropriate forest plots were generated according to the weighted effects and pooled survival was calculated.

A Funnel plot was generated for estimation of bias.

A meta-regression was then performed for the study design (prospective vs. retrospective), the study setting (private clinic vs. university), and the analysis for the reasons of failure and the type of restoration (Inlays vs. onlays), the type of tooth (Molar vs Premolars) in which failures occur more was done.

The quality of the included articles was assessed with the Cochrane collaborations tool for assessing risk of bias for RCTs and Newcastle Ottawa scale for observational studies.

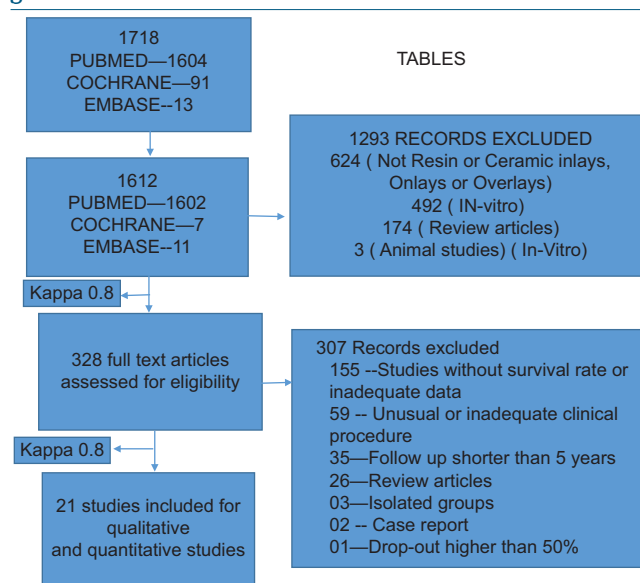
## RESULTS

### Study selection

The search strategies employed yielded 1718 studies [Table 1]. After the titles and abstracts were evaluated and duplicates were eliminated, 328 articles were identified; after title and abstract revision 307 of these were excluded.

Finally, for quantitative analysis as well as analysis of risk of bias 21 articles were included.

**Table 1: Flow diagram with the information through the phases of study selection based on Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines<sup>[45]</sup>**



**Table 2: All studies published in English**

Author	Year	Materials	Country	Evaluation criteria	Follow up (mean)	Age	Patients	Dropout study	In/on/over	Survival (%)	U or P
Kennet <i>et al.</i> <sup>[14]</sup>	2020	GC	USA	NS	10.9	20-99	304	0	RC A=246, B=305	93.6/98.3	P/NS OP
Starsding <i>et al.</i> , 2020 <sup>[20]</sup>		GC (IPS)	Swedish	Modified USHPS	11.2±4.3	50.9	54/36	33.30%	PC A=107, B=25	80.4/80.0	P/NS OP
Irusa <i>et al.</i> <sup>[17]</sup>	2020	NS (FP+GC)	USA	NS	22 years	NS	NS	NS	B=987	81.80	U/4 OP
Archibald <i>et al.</i> , 2017 <sup>[13]</sup>		GC	Canada	Modified USHPS	6 years	24-80	52/22	44	RC B=65	67.40	U/3 OP
Otto <i>et al.</i> <sup>[34]</sup>	2017	FP	Switzerland	Modified USHPS	26 years 10 month	NS	108/65	39%	RC A=100, B=100	87.50	P/2 OP
Beier <i>et al.</i> <sup>[15]</sup>	2012	GC	Austria	CDA/Ryge	12a, 20b	14-72	120	0%	RC 213a/234b	92.4a/81.5b	U/2 OP
Frankenberger <i>et al.</i> <sup>[18]</sup>	2008	GC	Germany	Modified USHPS	12 years	20-57	34/26	23.5	PC 96/58	86	U/6 OP
Otto and Schneider <i>et al.</i> <sup>[32]</sup>	2008	Feldspathic porcelain	Switzerland	Modified USHPS	17 years	17-75	108/89	17.59	RC 200/187	88.70	P/1 OP
Krämer <i>et al.</i> <sup>[5]</sup>	2008	GC	Switzerland	Modified USHPS	8 years	24-54	31/23	25.8	PC 94/68	90	U/6 OP
Thordrup <i>et al.</i> <sup>[43]</sup> (a)	2006	NS (FP + GC)	Denmark	CDA/Ryge	10 years	NS	37	0	RC 29	80	P/NS OP
Thordrup <i>et al.</i> <sup>[44]</sup> (b) (resin)	2006	Resin	Denmark	CDA/Ryge	10 years	NS	37		30	80	P/NS OP
Reiss <i>et al.</i> <sup>[36]</sup>	2006	NS (FP + GC)	Germany	CDA/Ryge	18.3 years	12 years-70 years	299	0	RC 1011	89	P/NS OP
Schulte <i>et al.</i> <sup>[39]</sup>	2005	GC	Germany	NS	9.6 years	17-64	434/390	10.13	RC 810/783	90	U/244 OP
Smiles <i>et al.</i> <sup>[42]</sup>	2004	Feldspathic porcelain	Australia	NS	6 years	15-50	50	0	RC 78	60.5±6.3	P/2 OP
Sjogren <i>et al.</i> <sup>[41]</sup>	2004	Feldspathic porcelain	Sweden	Modified USHPS	10 years	26-73	27/25	7.4	RCT 66/61	89	U/3 OP
Schulz <i>et al.</i> <sup>[40]</sup>	2003	Feldspathic porcelain	Sweden	CDA/Ryge	9 years	28-79	52/51	1.92	RC 109/107	84	P/1 OP
Posselt and Kerschbaum <i>et al.</i> <sup>[33]</sup>	2003	Ceramics (NS)	Germany	NS	9.1 years	17-75.7	794	NS	RC 2328	95.50	P/NS OP
Hayashi <i>et al.</i> <sup>[16]</sup>	2000	Feldspathic porcelain	Japan	Modified USHPS	8 years	NS	29/25	13.79	RC 49/45	80	U/NS OP
Felden <i>et al.</i> <sup>[17]</sup> 1998		FP/GC	Germany	Modified USHPS	6.5 years	17-66	92	0	RC 287	98	U/5 OP
Fuzzi and Rappelli <i>et al.</i> <sup>[19]</sup>	1998	Feldspathic porcelain	Italy	Modified USHPS	10 years	21-58	67	0	RC 183	97	P/1 OP
Roulet <i>et al.</i> <sup>[38]</sup>	1997	GC	Germany	Modified USHPS	6 years	NS	30/29	3.33%	RC 137/123	76	U/NS OP

CDA: California Dental Association, NS: Not specified, PC: Prospective cohort, RC: Retrospective cohort, RCT: Randomized controlled clinical trials, USHPS: United States Public Health Service, U: University, P: Private, OP: Operators, Inl: Inlays, Onl: Onlays, Over: Overlays, GC: Glass-ceramic, IPS: EMPRESS, FP: Feldspathic Porcelain

## Study characteristics

The selected articles had been published between 1987 and 2020 [Table 2].

We found 1 RCT, 4 prospective studies, 16 retrospective studies. Most of the selected articles used modified USHPS as their evaluation criteria, 2 studies however used the CDA/Rye, and the evaluation criteria was not specified in 5 articles

## Grading of articles

The quality of the included articles was assessed with the Cochrane Collaborations tool for assessing risk of bias for RCTs and Newcastle Ottawa scale for observational studies.

## Measures and meta-regression analysis

In the ceramic group 8 studies used glass ceramics only whereas 6 studies used only feldspathic porcelain. 4 studies used both feldspathic and glass ceramic. There was no association between the ceramic types and the survival rates as seen from the meta-regression at 5 year ( $P = 0.916$ ) and 10 year ( $P = 0.811$ ).

In resin group 1 study evaluated only resins and 1 study compared resins and ceramics.

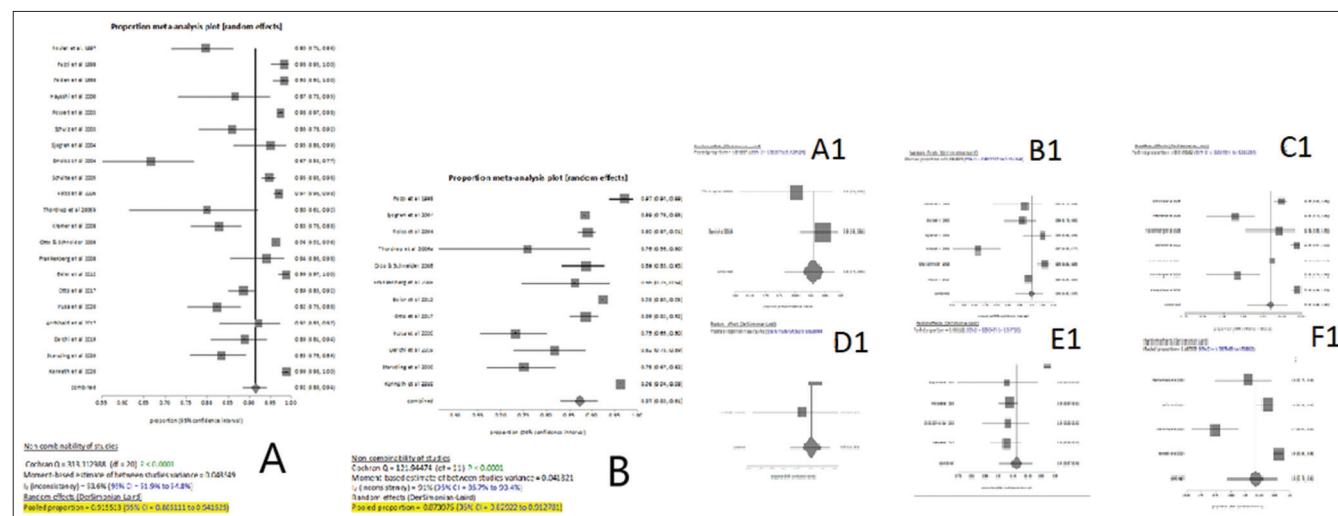
Funnel plots and standardized residual graphs [Appendix Figure 1] for 5-year survival allowed us to evaluate the homogeneous distribution in all 21 articles included. Since the  $I^2$  value was more than 50% we used the random effects model for the meta-analysis similarly, no association was seen between survival rate and the study design (prospective vs. retrospective) ( $P = 0.801$ ), study setting (private clinic vs. university) ( $P = 0.914$ ) or the follow-up time ( $P = 0.837$ ).

Because the maximum follow-up period of the included studies ranged between 6 and 20 year, all studies with a 5-year follow-up were included. However, only 12 studies with 10-year follow-up period were found. For studies in which the estimated survival was not definitive at the follow-up time, the value of survival rate was determined from the analysis of the survival curves given in the full text, supporting this assumption up to 5 years.

The rate of survival of the total pooled sample including resin, feldspathic porcelain and glass ceramic at 5-y follow-up was 92% ( $n = 7148$  restorations) (95% CI, 89%–94%;  $I^2 = 93.6\%$ ;  $P < 0.0001$ ) [Figure 1]. A meta-regression showed no significant survival difference between feldspathic and glass ceramic at 5 years ( $P = 0.916$ ). As only 2 studies with insufficient data were available for resins, it was not compared.

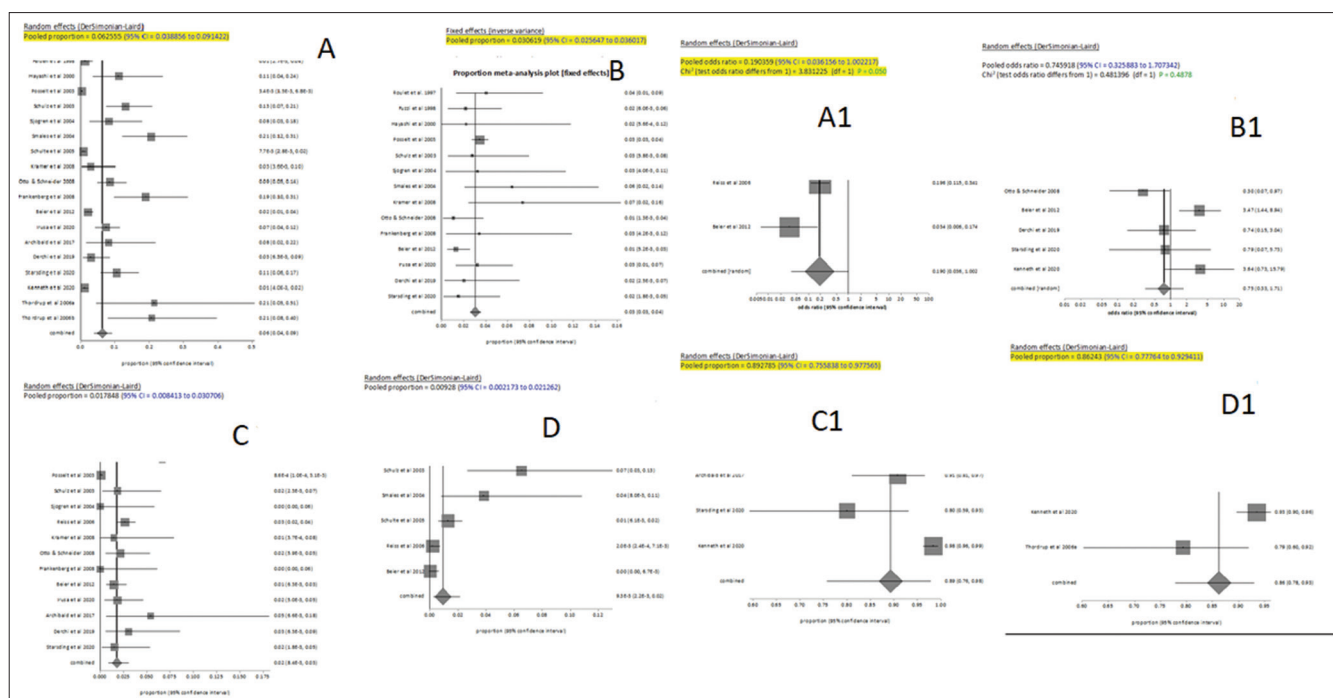
At 10-year follow up it was 87% (95% CI, 83%–91%;  $I^2 = 91\%$ ;  $P < 0.0001$ ) ( $n = 3185$ ) [Figure 1]. Similarly, a meta-regression showed no significant survival difference between feldspathic and glass ceramic at 10 years ( $P = 0.811$ ). Three studies (Kenneth *et al.* 2021, Starsding *et al.* 2020 and Bier *et al.* 2012) gave separate survival rates for inlays and onlays ceramic at 10 years ( $P = 0.811$ ). As only 2 studies with insufficient data were available for resins, it was not compared.

The survival rate of resin group at 5 years was 86% ( $n = 129$  restorations) (95% CI, 86%–96%;  $I^2 = 36.1\%$   $P = 0.211$ ), [Figure 1] at 10 years it was 75% ( $n = 115$ ) (95% CI, 67%–82%;  $P = 0.526$ ) [Figure 1]. The survival rate of feldspathic porcelain at 5 years was 90% ( $n = 1048$ ) (95% CI, 82%–95%;  $I^2 = 91.1\%$ ;  $P < 0.0001$ ) [Figure 1] and at 10 years it was 91% ( $n = 1829$  restorations) (95% CI, 87%–94%;  $I^2 = 78.6\%$ ;  $P = 0.0009$ ) [Figure 1]. The survival rate of Glass



**Figure 1:** (A) Forest plot of pooled studies for 5 years (B) forest plot of pooled studies for 10 years forest plot of pooled studies at 5 years for (A1) resins (B1) feldspathic porcelain (C1) glass ceramics forest plot of pooled studies at 10 years for (D1) resins (E1) feldspathic porcelain (F1) glass ceramics





**Figure 2:** Forest plot of subgroup for outcome on (A) fractures, (B) endodontic complications (C) caries and (D) debonding outcome of subgroups for (A1) vitality of tooth (vital vs. nonvital), (B1) type of tooth (premolar vs. molar), (C1) pooled survival rate of inlays, (D1) pooled survival rate of onlays (C and D) showing inlays versus onlays

ceramic at 5 years was 92% ( $n = 2218$  restorations) (95% CI, 86%–96%;  $I^2 = 94.4\%$ ;  $P < 0.0001$ ) [Figure 1], and at 10 years it was 89% ( $n = 1075$  restorations) (95% CI, 79%–96%;  $I^2 = 94.1\%$ ;  $P < 0.0001$ ) [Figure 1].

The comparison showed that at 5 years the resin group had a lower survival rate of ( $n = 129$  restorations) 86% as compared to ceramic group (FP: [ $n = 1048$  restorations] 90%, GC: [ $n = 2218$  restorations] was 92%). Similarly, even at 10 years the survival rate of resin group was lesser 75% ( $n = 115$ ) as compared to ceramic group (FP: [ $n = 1829$  restorations] was 91% and GC: [ $n = 1075$  restorations] was 89%).

### Meta-regression and analysis of subgroups

Failures of the total samples were described in 4 ways i.e., Fractures, Endodontic complications, Secondary caries and Debonding.

### Fractures

Fracture data was unavailable for 2 studies, namely Reiss *et al.* (2006) and Otto *et al.* (2017). The rest 19 studies the fractures/chipping rate for restorations was 6.2% (95% CI, 3.9%–9.1%) [Figure 2].

### Endodontic problems

Similarly, endodontic problems showed an incidence of 3.0% (95% CI = 2.5%–3.6%) ( $n = 128$  failures in 4233 restorations) [Figure 2].

Since the  $I^2$  value was  $<50\%$  ( $I^2 = 34.9\%$ ;  $P = 0.095$ ),

the extracted data were those obtained via fixed effect, showing that for both materials there was no difference in incidence.

### Secondary caries

The pooled incidence of secondary caries as determined by 14 studies ( $n = 59$  out of 5129 restorations) was 1.7% (95% CI = 0.8%–3.1%) ( $P < 0.0001$ ) [Figure 2].

### Debonding

According to the 6 studies mentioned below the pooled incidence of debonding was ( $n = 24$  out of 4854 restorations) was 0.9% (95% CI = 0.2%–2.1%) ( $P < 0.0001$ ) [Figure 2].

A differential analysis of the failure between the resin group and the ceramic group was done.

### Vital versus nonvital

A comparative meta-regression analysis was done for failures in vital teeth versus failures in nonvital teeth.

There were 3 studies which compared failures in vital teeth versus failures in nonvital teeth. Pulp vitality as well as endodontic problems were faced in such restorations, with an odds ratio (OR) of 0.19 (95% CI, 0.04–1.0;  $P = 0.050$ ) according to the 3 studies ( $n = 142$  of 2236 in vital teeth;  $n = 34$  of 132 in nonvital teeth) [Figure 2]. There was significantly lesser chance of failure in vital teeth compared to nonvital teeth.

### Premolar versus molars

The meta-analysis showed failures attributed to premolars versus molar had an OR of 0.74 (95% CI, 0.32–1.7;  $P = 0.4878$ ) according to 8 studies ( $n = 49$  of 867 in premolars;  $n = 82$  of 1468 in molars) [Figure 2]. The tooth type (premolars vs. molars). Showed no significant association between the incidences of failure.

### Inlay versus onlay

The pooled overall survival for onlays from 4 studies was 89.2% (95% CI = 75.5%–97.7%) ( $P < 0.0001$ ) [Figure 2].

The pooled survival for inlays from 5 studies was 86% (95% CI = 77%–93%) ( $P = 0.0017$ ).

There was no significant difference between the survival of inlays or onlays at 5 years ( $P = 0.771$ ).

### Study design

*There were 5 prospective trial and 16 retrospective cohorts*

A meta-regression analysis showed no significant difference on the survival based on study design ( $P = 0.801$ ).

The pooled overall survival (5 year) for prospective trials was 92% (95% CI, 89%–94%;  $I^2 = 88.4\%$ ;  $P < 0.0001$ ) whereas for retrospective data was 91% (95% CI, 88%–93%;  $I^2 = 94.3\%$ ;  $P < 0.0001$ ).

### Study setting

There were 11 trials conducted in private settings and 10 in the university setting. A meta-regression analysis showed no significant difference on the survival based on study design ( $P = 0.914$ ).

The pooled overall survival (5 year) for university trials was 91.4% (95% CI, 86%–95%;  $I^2 = 91.6\%$ ;  $P < 0.0001$ ) whereas for private practice was 91.4% (95% CI, 87%–95%;  $I^2 = 94.7\%$ ;  $P < 0.0001$ ).

There was no available conclusive evidence on the survival of resin or crystalline ceramic materials, evaluation of color, marginal integrity, wear, postoperative sensitivity, and patient satisfaction due to the lack and/or standardization of criteria reported. A meta-analysis of the 15-year duration, cementation technique, manufacturing method, and location (maxilla or mandible) could not be performed with the data that was available.

### Risk of bias of individual studies

All of the requisites could not be fulfilled by any of the retrospective studies, because items 9–12 and 25 were apt for prospective studies and/or RCTs. Therefore, a maximum value of 80.77% was expected to be achieved by the retrospective study. Nevertheless, sources of bias and

heterogeneity could have affected the stipulated items and were therefore tabulated to elaborate further on the statistical data. The percentage of bias was 93.6% in the articles included in meta-analysis [Table 1].

## DISCUSSION

In this study we chose Randomized control trials, retrospective studies, prospective studies, which enabled us to evaluate a larger number of patients as well as a wide variety of materials. The evolution of techniques and materials could also be frequently followed in such studies; therefore, the sample is continuously updated. Considering the heterogeneity, a Random-effects model was used for all analysis except for evaluation of failures due to endodontic problems in which the  $I^2$  value was  $<50\%$  ( $I^2 = 34.9\%$ ;  $P = 0.095$ ). Visual inspection was carried out for data from the meta-regression to assist in the evaluation of any possible sources of heterogeneity, considering standardized residual graph and funnel plots. In this study we could get the survival data of resin inlays, onlays with the two selected studies, which was not present in any of the previous systematic reviews. In the present study, the pooled survival rate of resin and ceramic inlays onlays and overlays at 5 years was 92% ( $n = 7148$ ), and at 10 years it dropped to 87% ( $n = 3185$ ), so these high percentages of survival rates of the partial coverage restorations authenticate for the recent shift of trend from full coverage restorations towards partial coverage restorations for various treatment modalities. We did the separate qualification of evidence of Observational studies and RCTs using Grading of Recommendations Assessment, Development, and Evaluation.

The meta-regression of the material subgroups gave us a survival percentages of resins (86%,  $n = 126$ ), feldspathic porcelain (90%,  $n = 1048$ ) and glass ceramic (92%,  $n = 2218$ ), at 5 years and a survival percentages of resins 75% ( $n = 115$ ), feldspathic porcelain 91% ( $n = 1829$ ), glass ceramic 89% ( $n = 1075$ ) so with these findings we could conclude that ceramic restorations survived more as compared to resin restorations. However, there was not a significant difference in the survival rate, one reasoning for the similar performance of feldspathic porcelain, glass-ceramics, and resin could be the adhesive cementation that may have likely compensated for mechanical differences between the three different materials. Vitreous ceramics are often stratified in Glass-ceramic frameworks. Because framework ceramics are stronger as compared to veneering ceramics, chipping or fracture of the latter can be observed.<sup>[12,13]</sup> With respect to the resin, the studies included have used hybrid composites with a higher filler content, and these hybrid composites have strength almost similar to ceramics.<sup>[12]</sup>

We observed that the chance of failure was 81% less in vital teeth than in nonvital teeth (OR-0.19) implying that for restoration survival, tooth vitality is a significant factor.

There was no significant association between the incidences of failure related to tooth type premolars versus molars (OR = 0.74), so it could be inferred that the tooth type does not affect the survivability of inlays, onlays and overlays. The pooled overall survival for onlays from 4 studies was 89.2% (95% CI = 75.5%–97.7%) ( $P < 0.0001$ ) and the pooled survival for inlays from 5 studies was 86% (95% CI = 77%–93%) ( $P = 0.0017$ ), there was no significant differences between the two, so the preparation type (cuspal coverage) did not affect the survivability of the restoration.

There were 5 prospective trial and 16 retrospective cohorts, a meta-regression analysis showed no significant difference on the survival based on study design ( $P = 0.801$ ), so this could mean that the study setting did not affect the survivability, hence further reviews on survivability can include both the study designs.

There were 11 trials conducted in private settings and 10 in the university setting.

The pooled overall survival (5 year) for university trials was 91.4% (95% CI, 86%–95%;  $I^2 = 91.6\%$ ;  $P < 0.0001$ ) whereas for private practice was 91.4% (95% CI, 87%–95%;  $I^2 = 94.7\%$ ;  $P < 0.0001$ ), A meta-regression analysis showed no significant difference on the survival based on setting type ( $P = 0.914$ ).

The failures were mostly due to fractures (6.2%), endodontic problems (3%), secondary caries (1.7%) and debonding was (0.9%). When separate regression analysis of failures (fractures and secondary caries) of resin and ceramics was done, to check which occurred more in which group as it is believed that the failures in ceramics mostly occur due to fracture unlike resins in which secondary caries can be the main cause. As there was only one study that had the data on failure of resins due to secondary caries we could not do an analysis, the pooled incidence of secondary caries in ceramic was 1.6%, and surprisingly the percentage of failures in ceramics due to fractures was 5.9% (95% CI = 3.5%–8.9%) and in resins it was 10% (95% CI = 0.1%–33%), which is attributable to the higher strength of ceramic as compared to resins. Failures due to fractures were highest, so more research should be directed towards strengthening of resins and ceramics and making them less brittle.

A positive aspect seen in this present study was enhancement in the description of data, methodological delineation and more robust statistics with recent clinical studies. Consequently, studies from 1997 to 2020 were included.

Of 328 full-text articles, during the selection process 306 were excluded because they did not report survival rates or present complete data for the analysis. On the idea of this review also as other previous systematic reviews on this subject, there's a scarcity of clinical evidence for survival on the simplest fabrication technique (CAD/CAM, pressable and stratified). Information on the survival of inlays, onlays, and overlays performing up to 15 years could also not be retrieved from the articles. With reference to implications for future clinical research, it'll be crucial for researchers to conduct randomized clinical studies that specialize in the comparison of techniques, materials and cavity preparations, with detailed samples. Standardization of the evaluation criteria, separation of survival and success rates, and data on censorship in survival graphs, dropouts, and failure types are needed.

## CONCLUSION

The meta-analysis indicates that the survival rate of inlays, onlays, and overlays remains high, regardless of the follow-up time period (5 years and 10 years) as well as the material, study setting and study design. Our results indicate that foremost frequent sort of failures are fractures. Survival rates are not seeming to be affected by the type of tooth, but vital teeth shows longer survival of restorations and onlays marginally performed better than inlays.

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Nil.

## Conflicts of interest

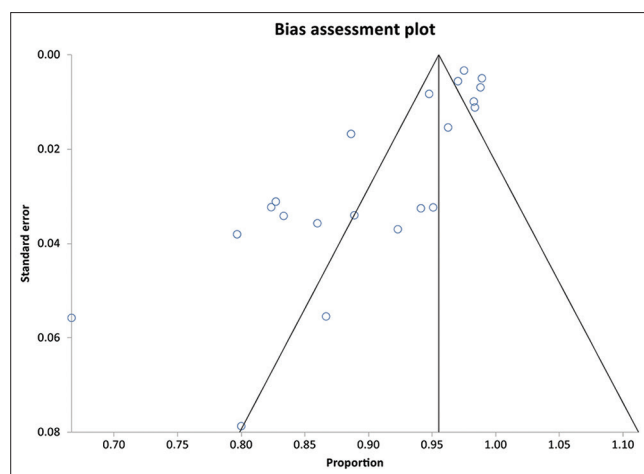
There are no conflicts of interest.

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**Appendix Figure 1:** Study Bias Assessment. Funnel plot and standardized residual graphs for 5-year survival allowed us to evaluate the homogeneous distribution in all 21 articles included

#### Bias indicators

Begg-Mazumdar: Kendall's  $-0.466667$   $P = 0.0021$

Egger: bias =  $-3.37638$  (95% CI =  $-4.672455$  to  $-2.080305$ )  $P < 0.0001$

Harbord: bias =  $-6.077035$  (92.5% CI =  $-9.192734$  to  $-2.961337$ )  $P = 0.0016$

#### Non-combinability of studies

Cochran  $Q = 313.112988$  (df = 20)  $P < 0.0001$

Moment-based estimate of between studies variance =  $0.048649$

$I^2$  (inconsistency) =  $93.6\%$  (95% CI =  $91.9\%$  to  $94.8\%$ )