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Comparative Clinical Outcomes of Partial and Full-Coverage Fixed Dental Restorations Using Hybrid Polymer and Ceramic CAD/CAM Materials: A Systematic Review and Meta-Analysis

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Abstract

This systematic review and meta-analysis investigated the clinical outcomes of tooth-borne partial and full-coverage fixed dental restorations produced from hybrid polymer–ceramic CAD/CAM materials, with emphasis on biological, mechanical, and esthetic performance. Literature searches were conducted in MEDLINE using a PICOS framework, and randomized controlled trials as well as case-control studies were screened independently by two reviewers with MeSH terms. Study quality and risk of bias were assessed through the Cochrane Collaboration tool and the Newcastle–Ottawa Scale. Pooled analyses were carried out to compare long-term survival at two intervals (≤24 months and ≥36 months), and complication rates were examined with R software ($p < 0.05$). Twenty-eight studies were included in the qualitative synthesis, and 25 in the quantitative analysis. Pooled survival was 99% (0.95–1.00) at ≤24 months, declining to 95% (0.87–0.98) at ≥36 months. Success rates followed a similar trend, with 88% (0.54–0.98) at ≤24 months and 77% (0.62–0.88) at ≥36 months. Differences across follow-up periods and among biological, technical, and esthetic outcomes (88% vs. 77%; 90% vs. 74%; 96% vs. 95%) were not statistically significant. A significant effect, however, was detected in the technical performance, favoring full crowns (93%; 0.88–0.96) over partial crowns (64%; 0.34–0.86). Although not statistically significant, partial crowns also showed lower biological (69%; 0.42–0.87 vs. 91%; 0.79–0.97) and esthetic (90%; 0.65–0.98 vs. 99%; 0.92–1.00) success compared with full crowns.

Keywords: Bonding, CAD/CAM, Composite resin cement, Dental restorations, Hybrid polymer, Indirect restorations, Meta-analysis, Systematic review

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Introduction

In the last two decades, the use of metal-free computer-aided design and computer-aided manufacturing (CAD/CAM) materials—particularly ceramics and composites—has significantly expanded in dentistry [1]. Their increasing popularity in restorative practice is largely attributed to favorable biological compatibility and esthetic properties, which align with rising patient and clinician expectations for minimally invasive yet visually pleasing outcomes [2, 3].

Advances in oral health have shifted treatment philosophies toward more conservative tooth preparations, modifying traditional indications and protocols to accommodate these novel metal-free alternatives [4, 5]. Parallel to these developments, contemporary dental care has emphasized efficiency, patient comfort, and cost-effectiveness. As a result, streamlined digital workflows integrating CAD/CAM systems have been introduced, enabling chairside fabrication of high-quality restorations with reduced clinical time and predictable outcomes [6, 7]. Such workflows allow the design and manufacture of partial and full-contour monolithic restorations—including inlays, veneers, single crowns (SCs), and fixed dental prostheses (FDPs)—that demonstrate esthetic appeal and precise marginal adaptation while remaining both time- and cost-efficient [3, 8].

Digital innovations have also driven the introduction of advanced restorative materials such as lithium disilicate (LD), lithium aluminosilicate reinforced with lithium disilicate (LD-LAS), hybrid polymer ceramics (HPC), and resin-matrix ceramics (RMC), including resin-based ceramics (RBC) and polymer-infiltrated ceramic networks (PICN) [9–11]. Among these, LD remains widely used owing to its clinical reliability, strength, and broad acceptance among patients and practitioners. LD-LAS demonstrates comparable flexural strength and esthetic properties, making it suitable for high-load applications [12, 13]. Hybrid materials—including HPCs, RMCs, RBCs, and PICNs—are gaining increasing attention because of their mechanical resilience, elasticity, and ability to support minimally invasive preparations while meeting esthetic demands of modern restorative workflows [11, 14].

Despite these advances, porcelain-fused-to-metal (PFM) restorations continue to be regarded as the benchmark for SCs and FDPs. However, PFMs have limitations such as compromised esthetics, greater tooth reduction requirements, and longer fabrication times. Consequently, metal-free options are becoming more attractive alternatives [15, 16]. Nevertheless, the long-term survival and complication profiles of these newer materials remain insufficiently documented, and clinicians must carefully assess material indications and processing methods on a case-by-case basis [14].

Given the diversity of hybrid polymer–ceramic CAD/CAM materials currently available for tooth-borne restorations, an evidence-based evaluation of their clinical performance is necessary. Accordingly, the present systematic review and meta-analysis was designed to examine the survival and success of partial and full-coverage CAD/CAM restorations fabricated from these materials. The study addresses the following PICO question: *In patients receiving tooth-borne partial or full crowns, are the survival and success rates of monolithic CAD/CAM restorations comparable to those of conventionally manufactured restorations?*

Experimental Section

Search strategy

An exploratory search was undertaken prior to refining the final research question, focusing on restorative material categories such as multiphase glass ceramics (for example, *Enamic*) and polymer-based systems (for example, *Lava Ultimate*), as well as their indications in tooth- and implant-supported single-unit reconstructions, including crowns and partial crowns. This preliminary work led to the formulation of the PICO framework, which specified tooth-borne partial or full crowns as the target population, monolithic CAD/CAM restorations as the intervention, conventionally fabricated restorations on natural teeth as the comparator, survival and clinical performance outcomes such as fracture, debonding, or functional behavior as endpoints, and randomized controlled trials together with case–control studies as the eligible study designs.

Systematic searches were then conducted across PubMed/MEDLINE, EMBASE, Web of Science, and the IADR abstract archive. Each database strategy combined controlled vocabulary and free-text keywords relating to four domains: the type of restoration (dental crowns, permanent restorations, full crowns, partial crowns, table tops), the manufacturing technology (CAD/CAM, CEREC, computer-aided or computer-assisted design and manufacturing, rapid prototyping), the restorative material (ceramics, porcelain, polymers, monolithic systems), and clinical outcomes (survival, survival rate, success, failure, complications, clinical behavior, chipping, debonding, and adverse events).

The full search syntax used in PubMed and EMBASE, developed in line with the PICOS question, is provided in **Table 1**. In EMBASE, additional limits were applied to exclude records already indexed in MEDLINE. Equivalent combinations of terms were adapted for Web of Science and IADR searches to ensure consistent and comprehensive coverage.

Table 1. Search strategy according to the focused question (PICO)

Focused Question (PICO)	**In Patients Receiving Tooth-Borne Partial or Full Crowns, Are Monolithic CAD/CAM Restorations Comparable to Conventionally Manufactured Restorations in Terms of Survival and Clinical Success Rates?**	
Search strategy	**Population**	Tooth-borne partial or full crowns. #1—((dental crowns [MeSH]) OR (dental restoration permanent [MeSH]) OR (full crown) OR (partial crown) OR (table top))
	Intervention	Monolithic CAD/CAM restorations. #2—((computer-aided design [MeSH])) OR (computer-assisted design [MeSH]) OR ((computer-aided manufacturing [MeSH])) OR (computer-assisted manufacturing [MeSH]) OR (cerec [MeSH]) OR (CAD/CAM) OR (rapid prototyping)) #3—((ceramics [MeSH]) OR (dental porcelain [MeSH]) OR (polymers [MeSH]) OR (monolithic))
	Comparison	Conventionally manufactured restorations. #4—((porcelain-fused to metal) OR (lost-wax technique)) #5—(dental alloys [MeSH])
	Outcome	Survival (rates) and/or clinical success. #6—((survival analysis [MeSH Terms]) OR (survival rate [MeSH Terms]) OR (survival)) #7—((success) OR (failure) OR (dental restoration failure [MeSH Terms]) OR (complications [MeSH Terms]) OR (clinical behavior) OR (adverse event) OR (chipping) OR (debonding))
	Search combination(s)	(#1) AND (#2 or #3) AND (#6 or #7)

Information sources

A systematic electronic search of the literature was performed in PubMed/MEDLINE, EMBASE, and Web of Science (ISI–Web of Knowledge), supplemented by Google Scholar and the IADR abstract archive, covering studies published up to 16 May 2018. The search was restricted to articles in English, limited to clinical trials and case–control studies conducted in humans, and published in peer-reviewed dental journals within the preceding five years. Search strategies were structured according to the PICOS framework, with terms organized into population, intervention, comparison, and outcome categories, each constructed using combinations of Medical Subject Headings (MeSH) and free-text terms.

Study selection and eligibility criteria

To reduce the risk of bias, two independent reviewers (N.A.-H.H. and T.J.) carried out the electronic search and study selection process. Titles and abstracts retrieved were screened in duplicate, and any discrepancies were resolved through discussion. Forty-eight potentially relevant articles were retrieved in full text, and final inclusion was based on pre-established eligibility criteria.

Studies were considered eligible if they met the following requirements: randomized controlled trial or case–control design, a minimum follow-up period of one year, and evaluation of either hybrid polymer or ceramic CAD/CAM restorative materials. Exclusion criteria included in vitro or in situ investigations, studies with less than one year of follow-up, and those assessing materials outside the scope of hybrid polymer or ceramic CAD/CAM systems. For the quantitative synthesis, only studies with control groups and available standard deviation values were retained. The screening and selection process is illustrated in **Figure 1**.

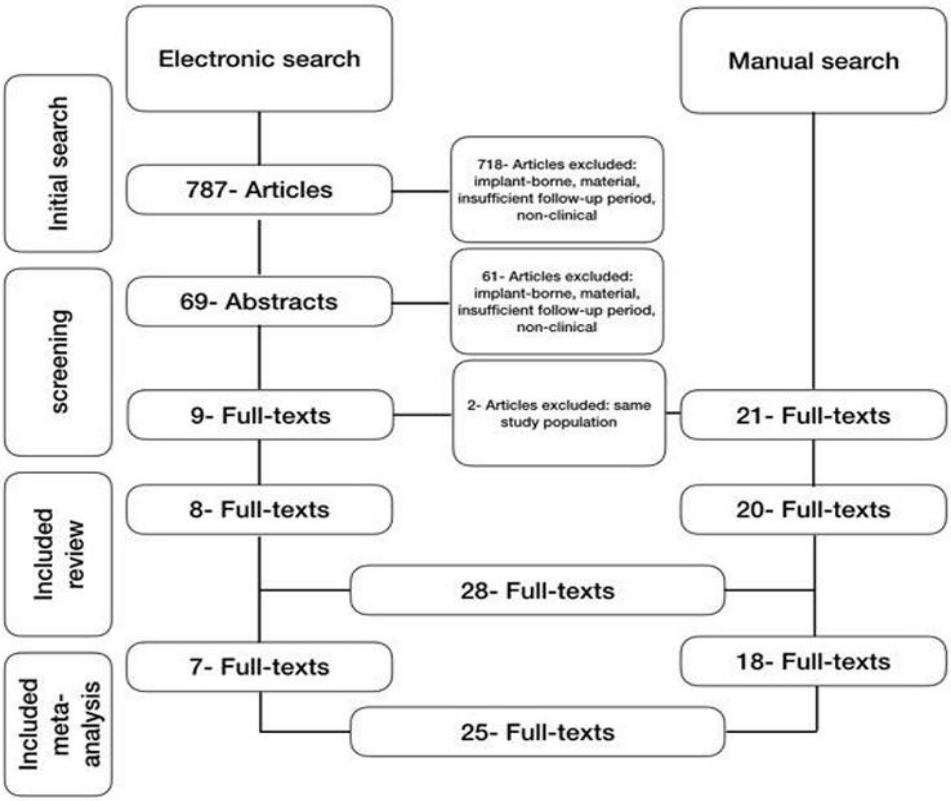

Figure 1. Flow diagram of the systematic search results

Data extraction and collection

Following the initial screening, abstracts meeting the inclusion criteria were retrieved in full-text form. In cases where abstracts did not provide enough detail to determine eligibility, the full texts were also obtained. Final inclusion decisions were made by two independent reviewers using a standardized extraction form. Data collected from each study included bibliographic information (title, authors, journal, year of publication), study characteristics (design, number of participants, number of restorations, restoration-to-patient ratio, duration of follow-up, and dropout rates), and details of the restorative procedures (material type and trade name, fabrication process, luting agent, failure events, survival, and success rates). Whenever possible, mean values and standard deviations for clinical outcomes—covering biological, technical, and esthetic failures—were extracted.

Corresponding authors were contacted to provide missing or unpublished data, and studies were only included in the analysis if the requested information was supplied. Clinical evaluation in the selected studies was primarily based on two standardized assessment systems: the modified United States Public Health Service (USPHS) criteria [17] and the World Dental Federation (FDI) criteria [18]. According to USPHS, restorations are assessed in terms of color stability, marginal adaptation, anatomical form, surface texture, marginal staining, presence of secondary caries, and surface luster, using three outcome categories (Alpha, Bravo, Charlie). The FDI system evaluates esthetic, functional, and biological properties on a five-point scale ranging from "clinically very good" to "clinically poor." Esthetic parameters include luster, staining, color match, translucency, and anatomical form; functional parameters include material fracture, retention, marginal and occlusal adaptation, wear, proximal form, radiographic findings, and patient perception; biological aspects address postoperative sensitivity, tooth vitality, caries recurrence, periodontal response, mucosal health, and general oral health.

Risk of bias assessment

The risk of bias for randomized trials was assessed using the Cochrane Collaboration tool, which considers sample size calculation, random sequence generation, adequacy of control groups, adherence to manufacturers' instructions, operator blinding, statistical analysis, allocation concealment, outcome reporting, and completeness of follow-up. Studies reporting one to three concerns were judged at low risk of bias, those with four or five issues were rated at moderate risk, and studies with six to nine concerns were classified as high risk. For non-randomized studies, the Newcastle–Ottawa Scale was applied, focusing on selection of study groups, comparability, and reliability of outcome assessment.

Data analysis

Statistical analyses were conducted using **R software (Version 3.5.3, R Core Team 2013)** [19]. Survival and

success rates were synthesized through meta-analysis employing logit transformation and random-effects modeling. Forest plots were generated to present pooled estimates, and funnel plots were used to assess potential publication bias. Analyses were performed at both the overall and subgroup levels, covering biological, technical, and esthetic outcomes. The restoration, rather than the patient, served as the unit of analysis. Studies lacking adequate information on sample size or follow-up duration were excluded. Due to limited sample sizes and incomplete reporting, all material types were pooled for statistical purposes. Only studies with at least 24 months of follow-up were included in the quantitative synthesis.

Results

Study selection

From an initial pool of 795 records, 48 articles were examined in full text for potential inclusion. Ultimately, 28 studies met the criteria for the systematic review, and 25 were suitable for the meta-analysis. Eight of the full texts were identified via electronic database searches, while the remaining 20 were found through manual searching. Of the studies included in the meta-analysis, 12 were randomized controlled trials, 14 were prospective studies, and two were retrospective studies [20–46].

Study characteristics

The 28 included studies, published between 1992 and 2018, collectively evaluated 1150 patients who received a total of 2335 restorations, with follow-up periods ranging from one to 18 years (mean 4.5 years). The investigations encompassed a wide array of restorative materials, including composite resins, feldspathic and leucite-reinforced ceramics, veneered and monolithic lithium disilicate, monolithic and veneered zirconia, and alumina. Fabrication methods varied and included indirect die-casting, incremental layering over stone dies, lost-wax veneering, chairside and laboratory CAD/CAM production, and vacuum injection molding. Luting strategies reported across studies included adhesive bonding systems, multiple resin cements (such as Panavia, Multilink, Variolink, Tetric, Multibond), and glass ionomer cements (e.g., Ketac).

Table 2. Quality assessment of included studies using the Newcastle–Ottawa scale

Study	Selection				Comparability	Outcome			Numbers of Stars (Out of 8)
	1	2	3	4	1	1	2	3	
Botto *et al.* [23]	–	★	–	–	★	★	★	★	5
Guess *et al.* [32]	★	★	★	★	★	★	★	★	8
Dhima *et al.* [25]	–	–	–	–	★	★	★	★	4
Dukic *et al.* [26]	–	–	–	–	★	★	★	★	4
Azevedo *et al.* [21]	★	★	★	★	★	★	★	★	8
Gehrt *et al.* [31]	★	★	★	★	★	★	★	★	8
Guess *et al.* [31]	★	★	★	★	★	★	★	★	8
Rauch *et al.* [39]	★	★	–	–	–	★	–	–	3
Reich *et al.* [40]	★	★	–	–	–	★	–	–	3
Santos *et al.* [41]	★	★	★	★	★	★	★	★	8
Santos *et al.* 2013	★	★	★	★	★	★	★	★	8
Taschner *et al.* [45]	★	★	★	★	★	★	★	★	8
Taskonak *et al.* 2006	★	★	–	★	★	★	★	–	6
Krejci *et al.* [34]	–	★	–	–	–	★	–	–	2

★: Each star corresponds to the subsection of quality assessment criteria.

Risk of bias in individual studies

The assessment of study quality and risk of bias for the randomized controlled trials is presented in Figure 2, while the evaluation for cohort and case–control studies is summarized in **Table 1**. Overall, the Cochrane Collaboration tool indicated a generally low risk of bias across the included RCTs. However, several studies lacked sufficient detail regarding random sequence generation, preventing definitive classification of risk in these domains [30, 36]. A number of studies also did not provide adequate information on allocation concealment [24, 28, 30, 36]. Only one trial demonstrated a high risk of bias due to unblinded outcome assessment.

For the non-randomized studies, the Newcastle–Ottawa Scale (NOS) was applied. Scores ranged from 2 to 8 points: one study scored 2, two studies scored 3, another two studies scored 4, one study scored 5, and seven studies achieved 8 points. These results indicate that, overall, the methodological quality of the included studies was acceptable for inclusion in this review.

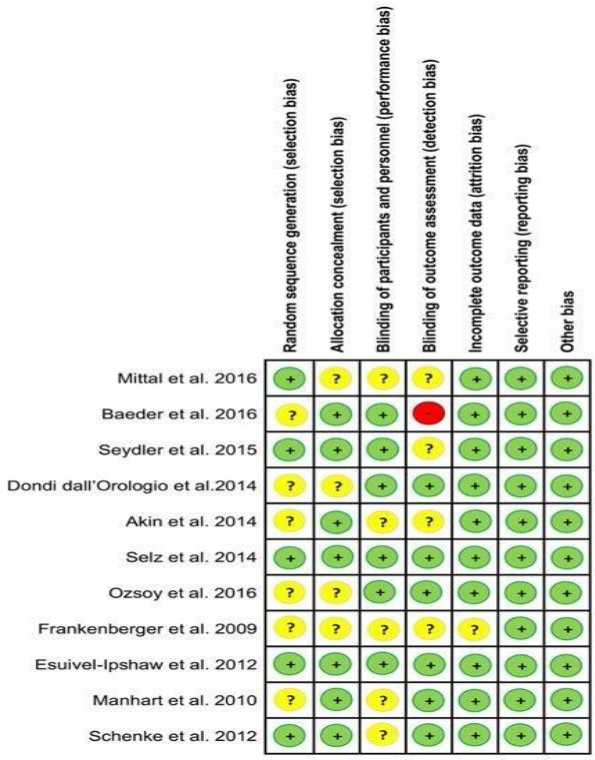

Figure 2. Summary of the Cochrane collaboration tool for assessing risk of bias for randomized controlled trials

Meta-Analysis

Quantitative synthesis was conducted using data from 25 studies. Pooled estimates of survival and clinical success for partial and full crowns were calculated and visualized using forest and funnel plots. Analyses were stratified according to two follow-up intervals: up to 24 months and 36 months or longer, as summarized in **Table 3**.

Table 3. Characteristics of included studies

Author/Year	Journal	Study Type	Participants (N)	Restorations (n)	Restoration-to-Participant Ratio	Follow-up Period	Drop-out	Material Used	Fabrication Method	Bonding Agent	Failures	Survival Rate	Success Rate	Evaluated Outcomes
Mittal *et al.* [36]	J Clin Ped Dent	Randomized Controlled Trial	50	50	1:1	3 years	None	Indirect resin composite (IRC) vs. stainless steel crowns (SSC)	IRC: Composite (3M Espe); SSC: Standard fabrication	IRC: Dual-cure resin cement (RelyX); SSC: Glass ionomer cement (Fuji I)	IRC: 3; SSC: 2	IRC: 82.9 %; SSC: 90.7 %	IRC: 100%; SSC: 95%	Modified FDI criteria, chairside treatment time, patient acceptability, marginal integrity (IRC < SSC), treatment time and esthetics (IRC > SSC)
Botto *et al.* [23]	Am J Dent	Retrospective Study	47	93	1.98:1	5–18 years	Not reported	Feldspathic porcelain onlays (13, Vitadur Alpha), IPS-Empress onlays (78), inlays (2)	Standard fabrication	RelyX	6 (6.5%)	93.5 %	93%	Gender, age, tooth preparation, restoration type/number/extent/location/quality/survival, ceramic material, luting resin, parafunctional habits, secondary caries, maintenance, marginal adaptation/discoloration, occlusal surfaces

Baader *et al.* [22]	J Adhes Dent	Randomized Controlled Trial	34	68	2:1	6.5 years	16 participants	Vita Mark II (Cerec 3D)	Indirect cast	RelyX with/without enamel etching	16: 11 RXU PCCs, 5 RXU+E PCCs (fractures: 3 RXU, 4 RXU+E; debonding: 4 RXU; endodontic treatment: 1 RXU; caries-related renewal: 1 RXU)	RXU: 60%; RXU+E: 82%	Not reported	Modified USHPS: postoperative hypersensitivity, anatomic form, marginal adaptation/discoloration, surface texture, recurrent caries
Seydler *et al.* [44]	J Prosthet Dent	Randomized Controlled Trial	60	60	1:1	2 years	None	Veneered zirconia (VZ) with lithium disilicate veneer; monolithic lithium disilicate (MLD)	MLD: Milled (Cerec MC XL, IPS e.max CAD); VZ: Zirconia framework (IPS e.max ZirCAD) with lithium disilicate veneer (Cerec MC XL)	Multilink (Ivoclar Vivadent)	None	100 %	Not reported	USHPS: marginal fit, color, technical/biologic complications
D'all' Orologio *et al.* [24]	Am J Dent	Randomized Controlled Trial	50	150	3:1	8 years	30 restorations, 10 participants	New restorative material (100), composite control (50, XP Bond ceram. x Duo Esthet. X)	Standard fabrication	XP Bond	7% (8 experimental, 4 control; failures due to sclerotic dentin, gingival margin issues)	93%	Not reported	Retention, sensitivity, marginal integrity, caries, contour

Akin *et al.* [20]	J Prosthodont	Randomized Controlled Trial	15	30	2:1	2 years	None	All-ceramic crowns	CAD/CAM and heat-pressed (HP) techniques	Varioilink II/Syntac (Ivoclar Vivadent)	None	100 %	Not reported	Porcelain fracture, partial debonding, secondary caries, abutment tooth extraction, esthetic/function impairment
Guess *et al.* [32]	Int J Prosthodont	Prospective Clinical Study	25	86	3.44:1	7 years	11 participants	All-ceramic veneers (overlap and full veneer designs)	Leucite-reinforced glass-ceramic (IPS Empress, Ivoclar Vivadent)	Varioilink II (Ivoclar Vivadent)	1 overlap veneer fracture, cohesive fractures/cracks in 12 participants	FV: 100 %; OV: 97.6 %	FV: 0.85 (CI: 0.70–1.00); OV: 0.70 (CI: 0.45–0.95)	USPHS criteria
Selz *et al.* [43]	Clin Oral Investig	Randomized Controlled Trial	60	149	>2:1	5 years	Not reported	In-Ceram Alumina crowns	Standard fabrication	Panavia (62), Super-Bond C&B (59), Ketac (28)	7.4% endodontic treatment, 5.4% secondary caries, 7.4% ceramic fractures, 1.3% debonding	Super-Bond: 91.6 %; Ketac: 87.4 %; Panavia: 86.3 %	Panavia: 82.2%; Super-Bond: 88.7%; Ketac: 80.1%	Secondary caries, fractures, root canal treatment, debonding
Özsoy *et al.* [38]	JAST	Randomized Controlled Trial	60	67	>1:1	2 years	2 teeth	Indirect composite onlays/ overlays	Indirect composite (Gradia, GC, Japan)	Varioilink II	None	100 %	Not reported	Anatomy, marginal adaptation/discoloration, color match, surface roughness, caries
Dhima *et al.* [25]	J Prosthet Dent	Retrospective Study	59	226	3.83:1	5 years	Not reported	Ceramic single crowns	Standard fabrication	Not specified	Not specified	95%	Not reported	Not specified

Dukic *et al.* [26]	Oper Dent	Prospective Study	51	71	1.39:1	3 years	Not reported	Indirect composite	Ormocer (35, Admira), Grandio (36)	Grandio with Voco Bifix QM	None	100 %	No significant difference	Modified USHPS
Azevedo *et al.* [21]	Braz Dent J	Prospective Study	25	42	1.68:1	1 year	None	Indirect resin composite	Incremental technique with LED curing (1000 mW/cm²)	Etched (ETR): Selective enamel etching + RelyX Unicem; Non-etched (NER): RelyX Unicem	None	100 %	99% excellent/good (Alpha 1/2), 0.9% sufficient (Bravo)	Modified USHPS
Fasbinder *et al.* [28]	J Am Dent Assoc	Prospective Study	43	62	1.44:1	2 years	1.6%	Lithium disilicate crowns (IPS e.max CAD)	Chairside CAD/CAM (CEREC 3)	Multilink Automix or experimental self-adhesive cement (Ivoclar Vivadent)	None	100 %	Not reported	Modified USHPS
Frankenberger *et al.* [29]	J Adhes Dent	Controlled Clinical Trial	34	96	2.82:1	12 years	40%	Leucite-reinforced glass ceramic (IPS Empress)	Manufacturer's instructions	Dual Cement (9), Varioilnk Low (32), Varioilnk Ultra (6), Tetric (49)	16% (15/96)	58–86%	Not reported	Surface roughness, color match, marginal integrity, tooth/inlay integrity, hypersensitivity
Frankenberger *et al.* [30]	Dent Mater	Randomized Controlled Trial	39	98	2.51:1	4 years	3%	Cergogold glass ceramic inlays	Dental ceramist, manufacturer's instructions	Multibond/Definite (45), Syntac/Varioilnk Ultra (53)	21 (inlay fracture: 11, tooth fracture: 4, hypersensitivities: 3, marginal gap: 3)	77–89.9 %	Not reported	Color match, marginal integrity, tooth/inlay integrity, sensitivity, proximal contacts

Gehrt *et al.* [31]	Clin Oral Invest ig	Prospective Study	41	104	2.54:1	9 years	4 participants, 10 crowns	Lithium-disilicate crowns	Lost-wax technique, experimental glaze	Adhesive (69.2%, Varioilnk II) or glass-ionomer (30.8%, Vivaglass)	4 (4.3%)	97.4% (5 years), 94.8% (8 years)	Not reported	Biologic/technical complications, minor chipping, endodontic issues, caries
Guess *et al.* [32]	Int J Prosthodont	Prospective Study	25	80	3.2:1	7 years	42 restorations	Lithium disilicate (40, IPS e.max Press), leucite-reinforced (40, ProCAD)	CAD/CAM (Cerec 3 InLab)	Tetric/Syntac Classic	1 restoration	Pressed: 100%; CAD/CAM: 97%	Pressed: 0.84 (CI: 0.70–0.98); CAD/CAM: 0.58 (CI: 0.38–0.78)	Modified USHPS, no secondary caries/endodontic issues, minimal cohesive fractures
Murgueitio *et al.* [37]	J Prosthodont	Prospective Study	99	210	2.12:1	3 years	Not reported	Leucite-reinforced IPS Empress onlays/ partial veneer crowns	Vacuum injection mold	Varioilnk II	33% (adhesive, cohesive, combined, decementation, sensitivity, pulpal necrosis)	96.66%	Not reported	USPHS, material thickness, tooth vitality, molar position, sensitivity, opposing dentition
Esquivel-Upshaw *et al.* [27]	J Prosthodont	Randomized Controlled Trial	32	37	1.16:1	3 years	1 restoration	Metal-ceramic (Pd–Au–Ag–Sn–In alloy, IPS d.SIGN), non-veneered/veneered lithium disilicate (IPS e.max Press, IPS Empress 2)	Standard fabrication	Varioilnk II	None	100%	Not reported	Tissue health, marginal integrity, caries, contacts, occlusion, surface texture, fractures, color match, sensitivity, wear
Manhart *et al.* [35]	Quintessence Int	Randomized Controlled Trial	89	155	1.74:1	3 years	Not reported	Artglass (35%), Charisma (21%) inlays	Light-cured in oven (Uni-XS, Heraeus Kulzer)	Solid Bond (Heraeus Kulzer)	5 Artglass, 10 Charisma (postoperative symptoms, bulk fracture, marginal integrity loss)	Not reported	Charisma better for restoration integrity	Modified USHPS

Rauch *et al.* [39]	Clin Oral Invest ig	Prospective Study	34	41	1.21:1	10 years	15 restorations	Monolithic lithium disilicate crowns	Chairside CAD/CAM	Multilink Sprint	5 (crown fracture, abutment/root fracture, endodontic issue, caries)	24/29	Not reported	Modified USHPS, low technical complications
Reich *et al.* [40]	Clin Oral Invest ig	Prospective Clinical Trial	34	41	1.21:1	4 years	12 restorations	Lithium disilicate crowns	Chairside CAD/CAM (Cerec)	Multilink Sprint	1	96.3%	28 (83% complication-free at 4 years, 71% at 4.3 years)	Modified USHPS
Santos *et al.* [41]	Clin Oral Invest ig	Prospective Clinical Trial	35	86	2.46:1	5 years	17.91% restorations	Sintered Duceram, pressable IPS Empress	Poured with dental stone type IV	Variolink II	8 (4 IPS fractures, 2 secondary caries, 2 marginal defects)	56 (87%)	Not reported	Modified USHPS, marginal discoloration/integrity, surface texture
Schenke *et al.* [42]	Clin Oral Invest ig	Randomized Controlled Trial	29	58	2:1	2 years	None	Ceramic blocks (Vita 3D Master CEREC Mark II)	Indirect method on die cast, CEREC III	RelyX Unicem with/without enamel etching	4	54	Not reported	Modified USHPS, marginal adaptation/discoloration changes
Taschner *et al.* [45]	Dent Mater	Prospective Controlled Study	30	83	2.77:1	2 years	None	IPS-Empress inlays/onlays	Commercial dental laboratory	RX (43), Syntac/Variolink II low viscosity (40)	1	82/83	RX lower tooth/marginal integrity	Surface roughness, color match, anatomic form, marginal integrity, tooth/inlay integrity, proximal contact, sensitivity, radiographic check, satisfaction

Taskonak *et al.* [46]	Dent Mater	Prospective Clinical Trial	15	40	2.67:1	2 years	Not reported	Lithia-disilicate (Empress II) FDPs/crowns	Standard fabrication	Not specified	10 (50% FPD catastrophic failures)	Not reported	Not reported	Marginal adaptation, color match, secondary caries, visible fractures
Krejci *et al.* [34]	Quintessence Int	Prospective Clinical Trial	10	10	1:1	1.5 years	None	IPS/Empress inlays	Manufacturer's instructions	Dual-curing composite (Dual Cement, Vivadent)	None	100 %	1 hypersensitivity, marginal discoloration	Modified USHPS

Survival ratios

Analysis of survival data indicated that restorations demonstrated an estimated survival rate of 99% within the first 24 months, which decreased to 95% for follow-up periods of 36 months or longer. Forest and funnel plots for the ≤24-month interval showed consistent findings with moderate heterogeneity (I^2 = 47%, p = 1.00) and minimal indication of publication bias. In contrast, analyses for the ≥36-month follow-up revealed substantial heterogeneity (I^2 = 93%, p < 0.01) and a modest potential for publication bias **(Figures 3–7)**.

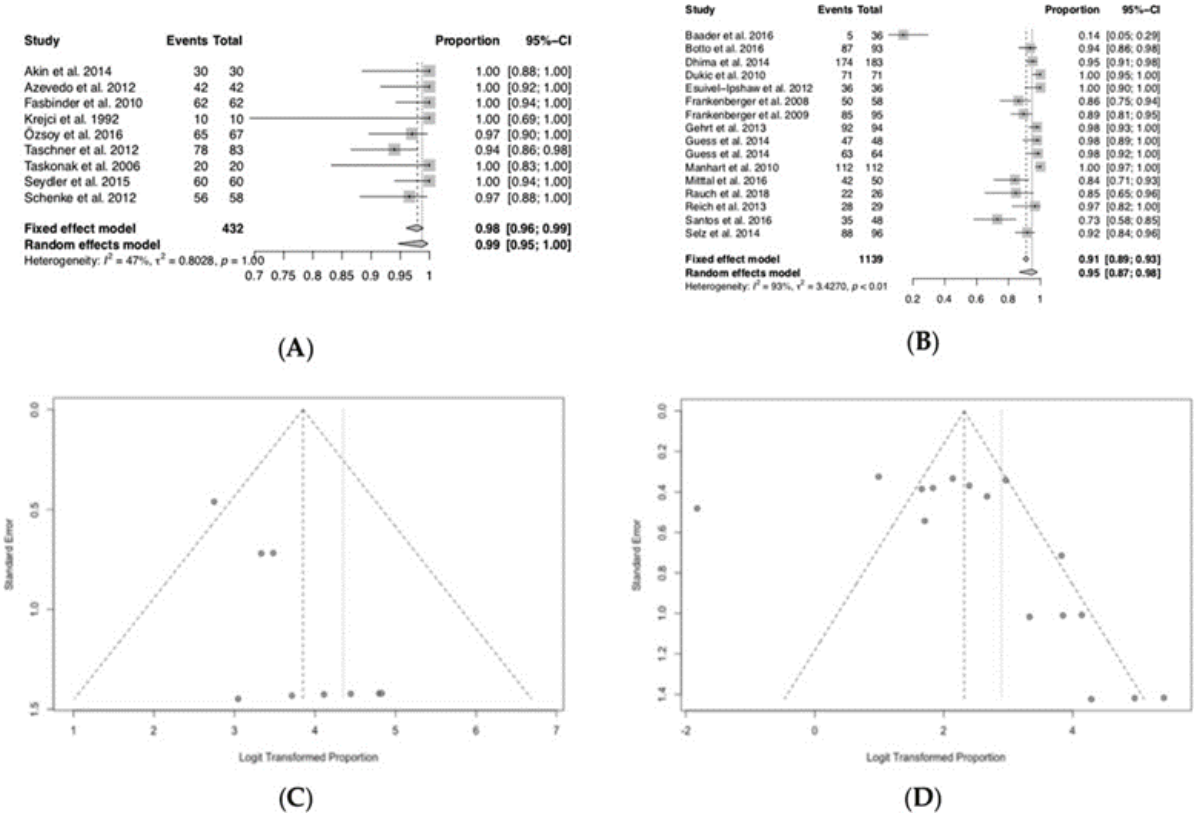

Figure 3. Survival ratios of all included specimens. (A) Forest plot ≤24 months; (B) forest plot ≥36 months; (C) funnel plot ≤24 months; (D) funnel plot ≥36 months

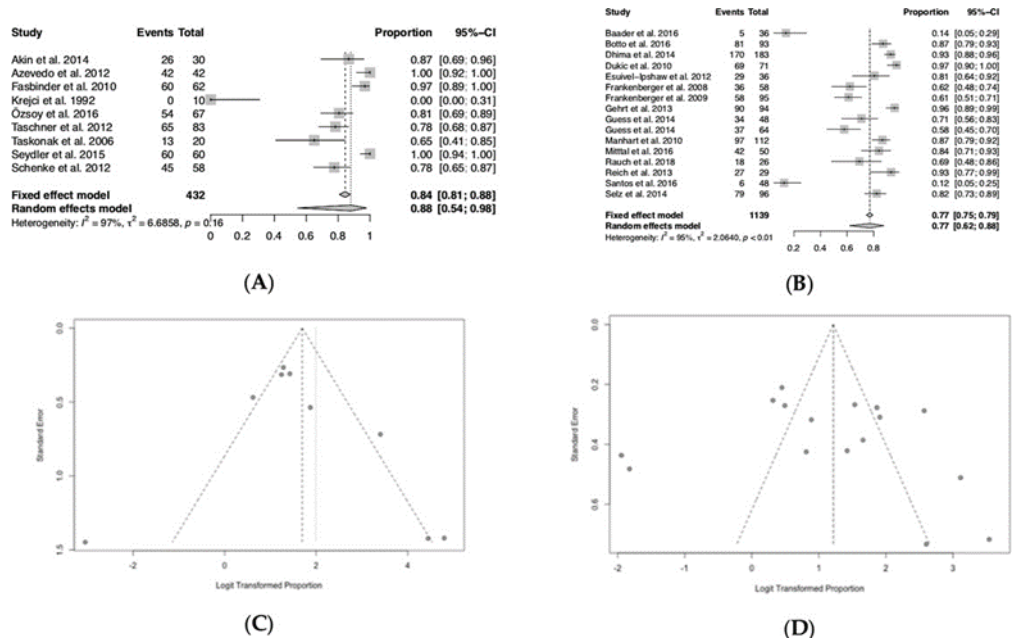

Figure 4. Success ratios of all biologic, technical and esthetical aspects. (A) Forest plot ≤24 months; (B) forest plot ≥36 months; (C) funnel plot ≤24 months; (D) funnel plot ≥36 months

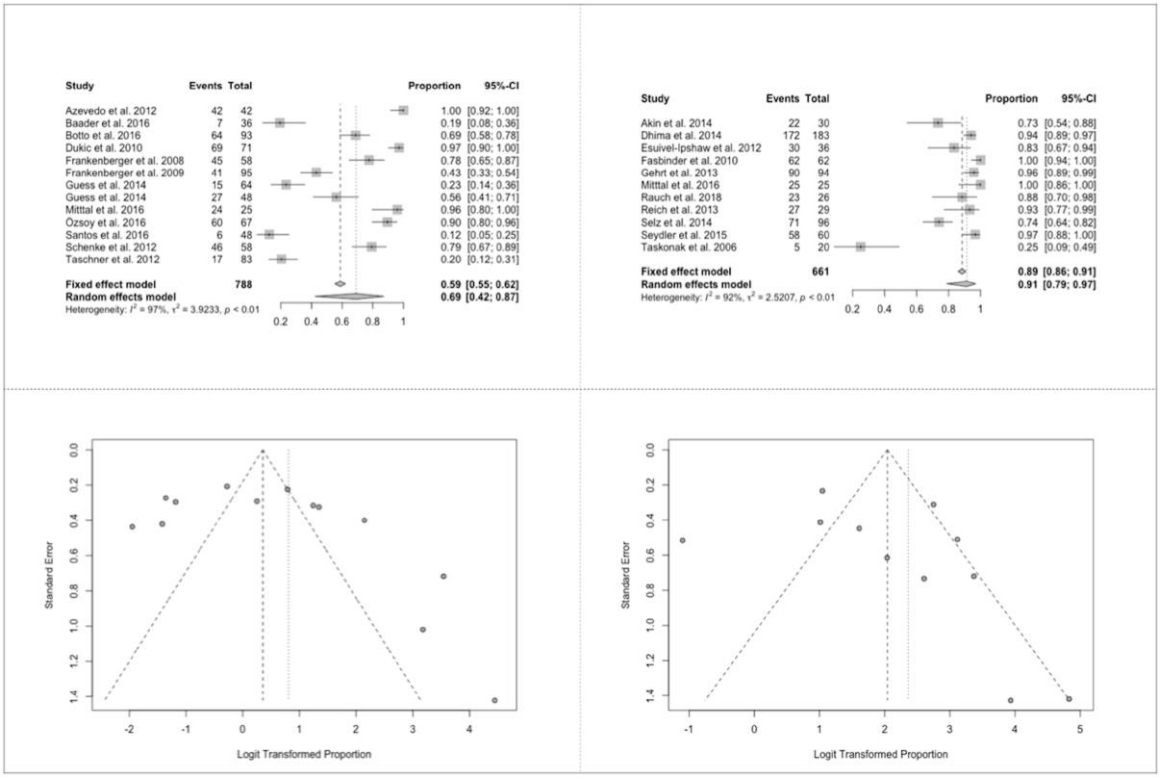

Figure 5. Success ratios of all biologic aspects. (A) Forest plot for partial and (B) full crowns; (C) funnel plot for partial and (D) full crowns

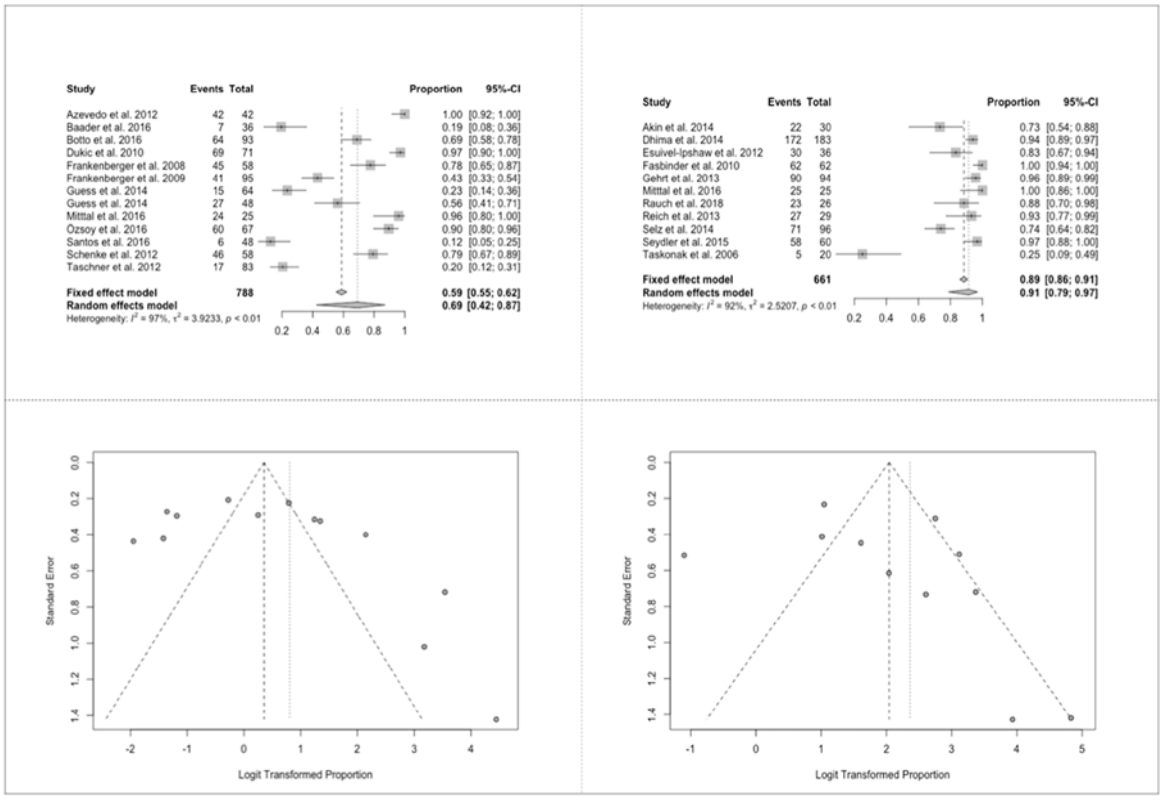

Figure 6. Success ratios of all technical aspects. (A) Forest plot for partial and (B) full crowns; (C) funnel plot for partial and (D) full crowns

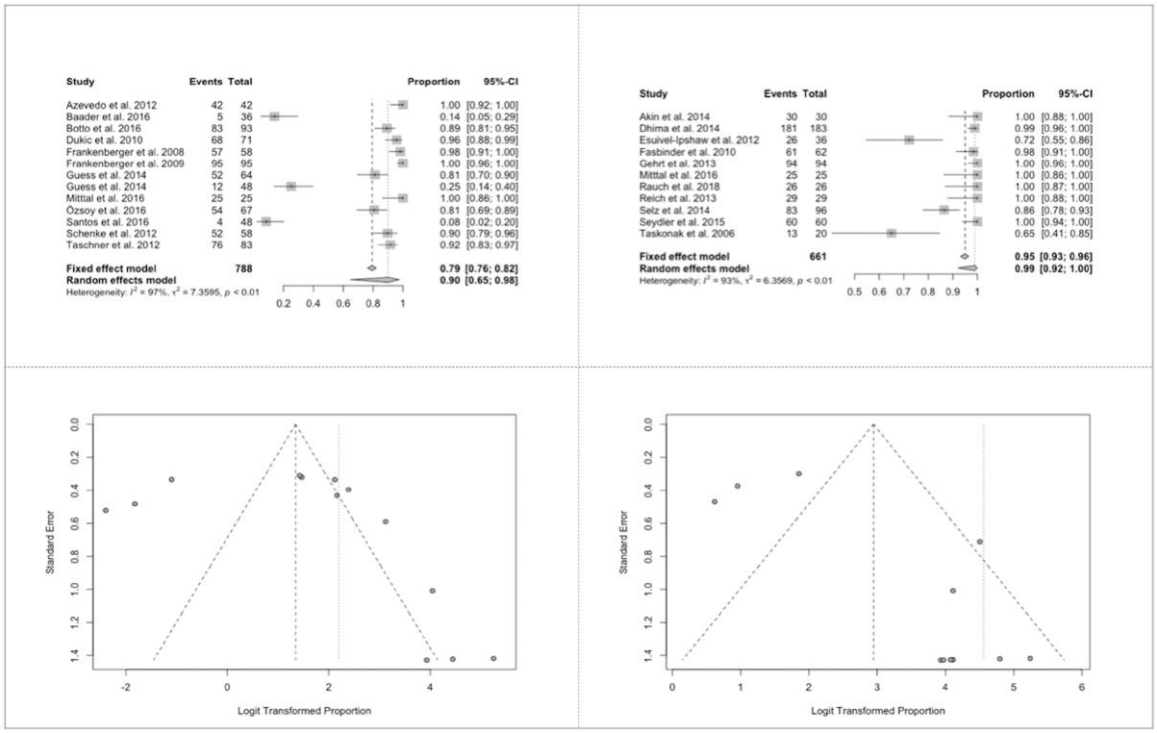

Figure 7.

Success ratios

Overall success

Across all studies, the pooled success rate of restorations up to 24 months was estimated at 88% (95% CI: 0.54–0.98), declining to 77% (95% CI: 0.62–0.88) for follow-ups of 36 months or longer. For the ≤24-month interval, the forest plot suggested moderate heterogeneity (I^2 = 97%, p = 0.16), which was not statistically significant. The corresponding funnel plot showed an uneven spread with some extremely small and large values. In contrast, for follow-ups ≥36 months, forest plots revealed substantial heterogeneity (I^2 = 95%, p < 0.01), reflecting the variability in materials, fabrication methods, and luting

agents across the included studies. This diversity prevented meaningful subgroup analyses based solely on material type.

Biologic outcomes

The estimated success rate for biologic criteria was 88% (95% CI: 0.58–0.97) within the first 24 months, decreasing to 75% (95% CI: 0.56–0.88) at 36 months or longer. Forest plots for both intervals demonstrated considerable heterogeneity (I^2 = 96–97%, $p < 0.01$), with large variability among study outcomes. Funnel plots for the ≤24-month interval suggested a slight skew towards higher reported success rates, indicating potential publication bias. For the longer follow-up period, the funnel plot showed widespread dispersion, consistent with the heterogeneous nature of the studies.

Technical outcomes

Technical success was estimated at 90% (95% CI: 0.74–0.97) for the first 24 months, dropping to 74% (95% CI: 0.50–0.89) after 36 months. Heterogeneity was high across both intervals (I^2 = 93–97%, $p < 0.01$). The funnel plot at 24 months indicated a tendency for overrepresentation of studies with very high success rates, reflecting variability in reporting and methodology.

Esthetic outcomes

Esthetic success was consistently high, with 96% (95% CI: 0.87–0.99) at ≤24 months and slightly decreasing to 95% (95% CI: 0.78–0.99) at ≥36 months. For the shorter follow-up, forest plots showed non-significant heterogeneity (I^2 = 86%, $p = 0.08$), whereas at ≥36 months, heterogeneity increased markedly (I^2 = 97%, $p < 0.01$), largely due to three studies reporting success rates of only 8–25%, while the remaining studies exceeded 72%. Funnel plots did not indicate bias for the first two years, though the three low-success studies contributed to variation at longer follow-up. Overall, no major publication bias was evident.

Comparison between partial and full crowns

Biologic success rates were higher for full crowns than partial crowns. Both forest plots for partial (I^2 = 97%, $p < 0.01$) and full crowns (I^2 = 92%, $p < 0.01$) revealed considerable heterogeneity. Funnel plots suggested possible publication bias for partial crowns but minimal bias for full crowns. Technical outcomes also favored full crowns, which demonstrated significantly higher success than partial crowns ($p < 0.05$). Forest plots indicated heterogeneous results for partial crowns (I^2 = 98%, $p < 0.01$) but relatively homogeneous outcomes for full crowns (I^2 = 66%, $p = 0.63$). Funnel plots suggested a possible bias in studies reporting high success rates.

Esthetic success followed a slightly different pattern. Partial crowns showed higher esthetic success than full crowns in some cases, though differences were less pronounced compared to biologic and technical outcomes. Forest plots for partial crowns (I^2 = 97%, $p < 0.01$) were strongly heterogeneous due to three studies reporting low success rates, while the remaining studies reported high outcomes. For full crowns, forest plots (I^2 = 93%, $p < 0.01$) also indicated heterogeneity, primarily due to two studies reporting low results. Funnel plots showed high success rates for most studies but included a few low outliers. The small number of studies with low results prevented definitive conclusions regarding potential bias.

Discussion

This systematic review and meta-analysis aimed to evaluate the clinical performance of partial and full crowns fabricated from hybrid polymer and ceramic CAD/CAM materials, focusing on both short- and long-term survival, as well as biologic, technical, and esthetic outcomes. While some data exist regarding the influence of CAD/CAM processing techniques on restoration survival, to our knowledge, no prior systematic review has comprehensively addressed survival and complication rates specifically for hybrid polymer and ceramic materials. These materials are relatively recent developments, and their clinical indications and long-term applicability are still being established. The present review highlighted a notable diversity in material composition and clinical application, reflecting the ongoing evolution in this field.

Meta-analytical results were stratified by follow-up period to examine long-term survival as well as biologic, technical, and esthetic complications for partial versus full crowns. Due to the heterogeneity in material types, compositions, and clinical protocols, it was not feasible to perform a meta-analysis based solely on material category. Similar observations regarding material heterogeneity were reported by Alves de Carvalho *et al.* [47], who reviewed CAD/CAM single restorations with at least three years of follow-up, noting substantial variability in materials and study design. Likewise, Rodrigues *et al.* [48] reported lower long-term survival of CAD/CAM restorations compared to conventional techniques, with a 1.84-fold higher failure rate over follow-ups of 24 to 84 months. In contrast, the current review found that hybrid polymer and ceramic restorations achieved an overall survival of 99% (0.95–1.00) at ≤24 months, decreasing slightly to 95% (0.87–0.98) at ≥36 months.

The type of restoration influenced outcomes, with full crowns demonstrating higher clinical performance than partial crowns across most measures. Comparable results have been reported in the literature, including five-year survival rates of 96.6% for leucite- or lithium-disilicate–

reinforced glass ceramics and 96% for sintered alumina and zirconia crowns [16]. Similarly, partial restorations in this review aligned with previous findings, such as the 97% five-year survival reported for CAD/CAM restorations by Sampaio *et al.* [49].

Contemporary trends indicate a preference among both clinicians and patients for esthetic, metal-free restorations. Despite this, porcelain-fused-to-metal crowns remain the gold standard for full coverage due to consistently high five-year survival rates exceeding 95% [16, 50]. Several studies suggest that CAD/CAM-fabricated ceramic crowns, both full and partial, may have slightly lower long-term survival compared to conventional techniques [48]. For full ceramic crowns, five-year survival rates of 95–96.6% for leucite- or disilicate-based ceramics are comparable to the findings in the present review. Zirconia crowns demonstrate slightly lower survival, with five-year rates around 91.2% (82.8–95.6%) [16].

Advances in digital workflows, material development, and adhesive techniques have enabled minimally invasive approaches, particularly for partial restorations. Historically, composite resins were considered less predictable for direct restorations, and long-term success of partial crowns has been influenced by material choice, patient factors, and clinician experience. Prior studies reported five-year survival rates ranging from 90.9% to 95% and ten-year rates around 91% for inlays and partial crowns [51]. Gold alloys were traditionally the benchmark for partial restorations; however, high cost and increasing esthetic demands have driven the adoption of hybrid polymer and ceramic CAD/CAM materials. Evidence for gold restorations indicates survival rates of 95.4% in a large retrospective study over more than 20 years [52], while other evaluations of posterior gold inlays report 82.9% success over a mean follow-up of 11.6 years [53].

The development of high-strength ceramics, composite resins, and adhesive systems has facilitated hybrid materials that aim to address the limitations of gold restorations. Systematic reviews indicate five-year survival rates of approximately 95% for feldspathic porcelain and glass-ceramic restorations, decreasing slightly to 91% at ten years [54]. These findings support the potential of hybrid polymer and ceramic CAD/CAM materials as reliable alternatives for both partial and full crown restorations, while emphasizing the importance of material selection and clinical technique.

Recent advancements in composite resin materials, alongside ceramics and gold alloys, have increased their utilization in restorative dentistry due to improvements in mechanical properties. Previous reviews on resin-based restorations have produced inconclusive results regarding their longevity and survival compared to ceramic materials [55]. More recent investigations focusing on CAD/CAM restorations, including resin-matrix ceramics, reported an estimated five-year survival rate of approximately 82.5% for both full and partial crowns [47, 49].

Survival rates remain a fundamental measure of clinical performance. However, restorations are also subject to biologic, technical, and esthetic complications that can compromise both longevity and overall clinical success. In this review, pooled success ratios were 88% (95% CI: 0.54–0.98) at ≤24 months and 77% (95% CI: 0.62–0.88) at ≥36 months. The meta-analysis did not reveal significant differences between the two follow-up periods or across biologic, technical, and esthetic outcomes (88% vs. 77%; 90% vs. 74%; 96% vs. 95%). Nevertheless, technical performance differed significantly between restoration types, with full crowns demonstrating a higher success rate (93%, 95% CI: 0.88–0.96) compared to partial crowns (64%, 95% CI: 0.34–0.86; $p < 0.05$). Biologic and esthetic outcomes were comparable between full and partial crowns (biologic: 91% vs. 69%; esthetic: 99% vs. 90%), suggesting that full crowns may be preferable when technical failures are a concern.

Restoration failures, defined as events requiring repair or replacement, directly impact overall success rates. The decline in success observed from 24 to 36 months aligns with previous literature on ceramic, zirconia, and CAD/CAM single crowns, though the present results were generally higher [16, 48, 56]. Due to heterogeneity in reporting, specific analyses of biologic, technical, and esthetic complications were not possible, necessitating an overall complication assessment.

Biologic complications were primarily related to secondary caries, loss of pulp vitality, endodontic interventions, tooth fractures, and hypersensitivity. Success rates for biologic outcomes were 88% at ≤24 months and 75% at ≥36 months, with partial crowns exhibiting approximately 21% more complications than full crowns. This difference may be attributed to the clinical design of partial restorations, which can make caries detection more straightforward, whereas full crowns may conceal such issues. Additionally, biologic complication rates were lower for metal-ceramic full crowns compared to all-ceramic restorations [16, 57].

Technical complications included ceramic fractures, chipping, core failures, microleakage, and loss of retention. Chipping was the most commonly reported issue, occurring across metal-ceramic and all-ceramic restorations with no significant differences between materials. However, overall technical complication rates were higher in the present review compared to conventional and other CAD/CAM materials [16, 57]. Factors such as limited clinical experience with new hybrid materials, challenges in bonding, polymerization variability of resin cements, and potential enzymatic degradation of adhesives may contribute to these elevated failure rates [51].

Partial restorations exhibited a progressive increase in technical complications over time, while full crowns remained more stable. Contributing factors may include variability in CAD/CAM milling, particularly for chairside-fabricated partial crowns, which may lack consistent verification of material thickness and surface smoothness. Technical issues can also give rise to esthetic concerns, including discoloration or glaze wear. Esthetic outcomes were generally favorable at 36 months but remained slightly lower than in some previous studies. In posterior restorations, the biomimetic properties of the materials likely reduce the clinical detectability of esthetic deficiencies compared to anterior restorations.

Overall, the findings suggest that hybrid polymer and ceramic CAD/CAM crowns demonstrate five-year success rates comparable to those reported for other restorative materials. There is a trend toward lower failure rates for glass-matrix and polycrystalline ceramics compared to leucite- and feldspathic-based ceramics. However, the high survival rates observed for glass-matrix ceramics, resin-matrix ceramics, and polycrystalline ceramics should be interpreted cautiously, particularly for newer materials with shorter follow-up periods.

For inlays made from ceramic and resin-matrix ceramics, dual-curing agents are generally recommended to ensure complete polymerization throughout the restoration, including areas with limited light exposure. Most studies included in this review employed chemically or dual-light polymerized cements. Comparisons of cementation methods indicate that dual-curing systems yield higher clinical performance and lower failure rates than purely chemical cements [58].

This review also highlights considerable methodological heterogeneity among studies. Limitations included inconsistent study designs, lack of control groups, non-homogeneous material groupings, and relatively short follow-up durations. Future research should focus on more standardized study designs, ideally split-mouth randomized controlled trials, with comparable material types, CAD/CAM manufacturing protocols, and software systems. While many studies report high survival rates, outliers with low survival—such as Baader *et al.*, 2016—underscore the need for additional small studies to better understand factors contributing to lower outcomes.

Conclusion

Based on the pooled analysis of biologic, technical, and esthetic outcomes at different follow-up intervals, the main conclusions are as follows:

- Success rates declined after 36 months compared to 24 months across all parameters.
- Esthetic success rates were the highest, followed closely by technical and biologic success rates.
- No statistically significant differences were observed between the two follow-up periods or among biologic, technical, and esthetic outcomes.
- Full crowns consistently demonstrated higher biologic, technical, and esthetic success rates compared to partial crowns.
- Technical success rates of full crowns were significantly higher than those of partial crowns.
- Although esthetic success rates were higher than biologic or technical outcomes for both full and partial crowns, these differences were not statistically significant.

Overall, these findings support the reliability of hybrid polymer and ceramic CAD/CAM crowns, particularly full crowns, while highlighting the importance of careful material selection, cementation strategy, and standardized clinical protocols to optimize long-term outcomes.

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