Clinical Performance of CAD/CAM Tooth-Supported Ceramic Restorations: A Systematic Review

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Owing to an increased demand for safe and esthetically pleasing dental materials, ceramics have been developed and optimized to rehabilitate anterior and posterior teeth. This evolution in ceramic materials is directly related to the development of sophisticated processing technologies and systems for use in dental medicine, particularly computer-aided design/computer-assisted manufacture (CAD/CAM) technology. This study is a systematic review outlining long-term clinical survival rates of single-tooth restorations fabricated with CAD/CAM technology with a minimum follow-up of 3 years. A bibliographic search up to September 2016 was performed using two databases: MEDLINE (PubMed) and Embase. Selected keywords and well-defined inclusion and exclusion criteria guided the search of relevant results. All articles were first reviewed by title, then by abstract, and subsequently by a full text reading. Data were assessed and extracted through a standardized form. The pooled results were statistically analyzed, and the overall failure rate was calculated by random effects model. Reported failures were analyzed by CAD/CAM system, type of restoration, restorative material, and luting agent. From a total of 2,916 single-tooth restorations with a mean exposure time of 7.0 years and 351 failures, the failure rate was 2.17% per year, estimated per 100 restoration years (95% confidence interval [CI]: 1.35% to 3.51%). The estimated total survival rate after 5 years was 89.7% (95% CI: 88.1% to 91.1%). The overall survival rate of single-tooth ceramic restorations fabricated with CAD/CAM technology was similar to those conventionally manufactured.
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Increased concern with dental esthetics prompted the development of ceramic materials that were mechanically suitable for the rehabilitation of anterior and posterior teeth and capable of mimicking the natural dental structure.[1,2] Laboratory use of these materials has followed the evolution of the technologies used to process them. Although some ceramics can still be applied in a traditional way, most are now processed with CAD/CAM technology.[1] The CAD/CAM systems made it possible to standardize the quality of materials, reduce production costs, and standardize the manufacturing process.[3]

The introduction of such technology into clinical practice should ideally be based on scientific evidence. However, evidence-based data obtained from well-controlled investigations is rarely available. The systematic review of the available literature proposed in this paper sought to establish a starting point for reconciling current viewpoints regarding clinical survival rates of single-tooth restorations fabricated with CAD/CAM technology following more than 3 years of functional service.

Materials and Methods

This systematic review was conducted following the preferred report-

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Table 1 MEDLINE (PubMed) and Embase Search Strategy and Filters Applied

MEDLINE (PubMed)		
Processing technology		Type of indirect restoration
"Computer-aided design" [MeSH] OR "computer aided manufacturing" OR "CAD CAM" OR "computer dentistry" OR "computer milled prosthesis" OR "Cerec"	AND	"Crowns" [MeSH] OR "inlays" [MeSH]
Filters		
Humans, observational study, research support, multicenter study, randomized controlled trial, evaluation studies, controlled clinical trial, comparative study, clinical trial		
Embase		
Processing technology		Type of indirect restoration
"Computer-aided design" OR "Computer aided manufacturing" OR "CAD" AND "CAM" OR "computer" AND "dentistry" OR "computer" AND "milled" AND "prosthesis" OR "Cerec"	AND	"Tooth crown" OR "dental inlay"
Filters		
Humans, longitudinal study, prospective study, retrospective study, randomized controlled trial, controlled study, controlled clinical trial, comparative study, clinical trial		

ing items for systematic reviews and meta-analyses (PRISMA) statement[4] and the patient, intervention, comparison, outcomes (PICO) method[5] as applicable in relation to the topic of the review:

- Patient: Adults
- Intervention: CAD/CAM single-tooth ceramic restorations
- Comparison: Conventional ceramic restorations
- Outcomes: Long-term survival rates
- Focused Question: What is the long-term survival rate obtained by CAD/CAM single-tooth restorations compared to conventional ceramic restorations in an adult population with a minimum follow-up of 3 years?

Information Sources and Data Extraction

An electronic search of publications was performed in two electronic databases, MEDLINE (PubMed) and Embase Library, with a platform-specific search strategy consisting of combinations of controlled terms (MeSH/EMTREE) and text words. Restrictions regarding the type of study and target population were applied (Table 1). In addition, a manual search was conducted to screen the references of the included publications for relevant articles. Two reviewers (I.C., T.M) independently conducted the manual search, and any disagreement was resolved by consensus.

Screening Process

The search strategy used for MEDLINE (PubMed) was a combination of MeSH and text words, and the search strategy used for Embase was a combination of EMTREE and text words. Filters regarding the type of study and target population were applied on both electronic databases (Table 1).

The search was performed on September 22, 2016. There was no lower limit for the analyzed time frame. All data from both electronic databases were collected, and duplicates were deleted.

In addition, the references of the selected articles were reviewed for possible inclusion. This search strategy is outlined in Fig 1. The titles and abstracts of all articles

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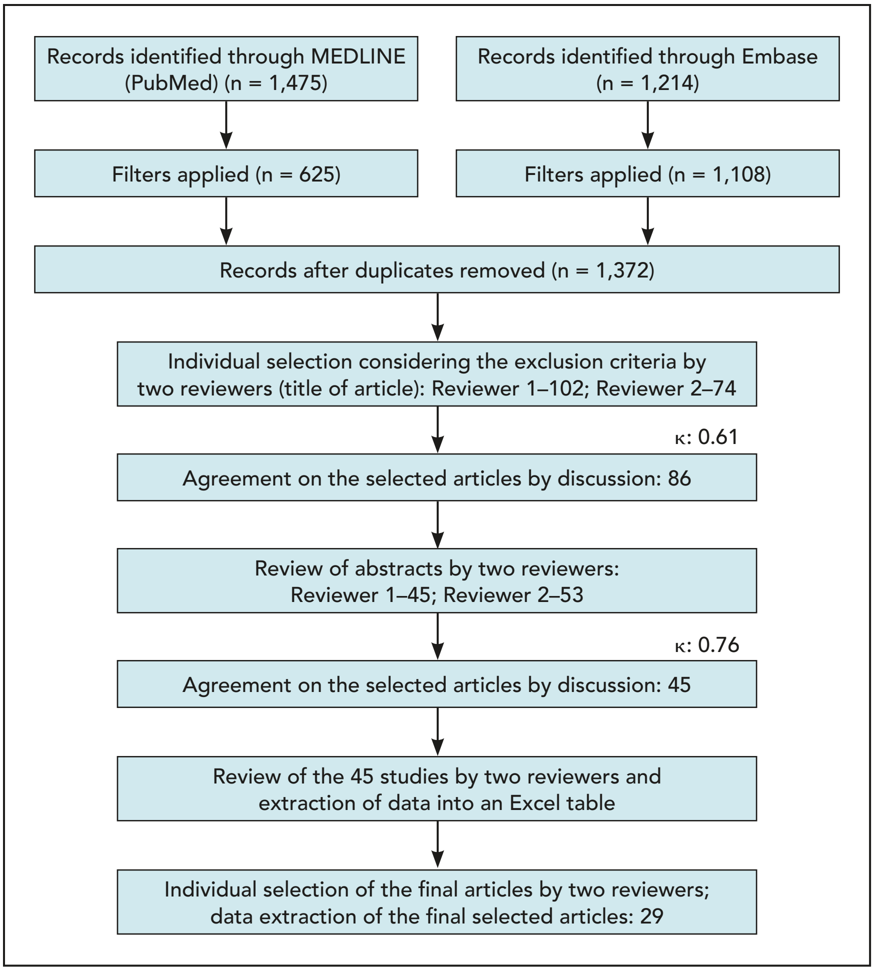

Fig 1 *Search design and strategy.*

Table 2 Inclusion and Exclusion Criteria

Inclusion criteria	Exclusion criteria
Written in English	Not written in English
In vivo study	Minimum follow-up < 3 y
Minimum follow-up of 3 y	Based on patients' charts
Subjects were adults aged ≥ 18 y	Based on questionnaires
	Case reports
	Animal studies
	In vitro studies

were reread and identified for possible inclusion by two independent reviewers. Reviewer agreement was statistically evaluated through Cohen's kappa test. Next, the full text of the article was read and cross-matched against the predefined inclusion and exclusion criteria shown in Table 2.

Study Classification

The data for each individual restoration were extracted from the selected studies and recorded on an Excel spreadsheet. The spreadsheets were organized by author, year, type of study (prospective/retrospective/randomized controlled trial [RCT]), restoration type, tooth location (anterior/posterior), CAD/CAM system, survival time (in years), restoration material, luting cement, and failure (yes/no). The restorations were categorized as core crown, crown, inlay/onlay, endo crown, reduced crown, and veneer.

Statistical Analysis

The effect size (failure rate) was defined in this study by dividing the number of events (failures) by the total time in function (years). The number of failures was extracted directly from the publications, while the total exposure time was calculated by multiplying the number of restorations by the mean exposure time in years. For each failure rate (estimated per 100 restoration years) the 95% confidence interval (CI) was calculated assuming a Poisson distribution.

After normalizing the data, it was possible to compare studies. Because the number of patients and thus the number of restorations varies from study to study, the size of the effect depends on the size of the sample. This difference can be overcome by assigning a weight to each study; in other words, the variability of the studies is weighted.

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Cochran Q test was performed ($P < .001$; 95% CI) to assess the heterogeneity among the selected studies. The presence of heterogeneity was analyzed through the inconsistency test ($I^2 \geq 50\%$). Since heterogeneity was > 50% (Q test and I^2), it was not possible to apply a fixed effects model. As a result, it could not be considered that all studies came from the same population and that there was homogeneity between them. Thus, the overall failure and the weight assigned to each study were determined using the random effects model. The 5-year survival rates were calculated for all parameters by the ratio of the event rate and the function S: $S(t) = \exp(-t \times \text{event rate})$.

Failure rates of CAD/CAM systems (commercial brands), restoration type (core crown, crown, inlay/onlay, endo crown, reduced crown, veneer), restoration material (glass-matrix ceramic, polycrystalline ceramic, resin-matrix ceramic), and luting cement (chemically, light-, or dual-cured) were estimated by random effects model.

Five-year survival rates were calculated for all factors as the relationship between event rate and survival function S, $S(t) = \exp(-t \times \text{event rate})$, assuming constant event rates were given. For each five-year survival rate, 95% CIs were calculated. To constrain S(t)'s confidence intervals to lie within the interval (0,1), they were calculated in a log scale [V(t)] (complementary log-log transform [CLL]), and posteriorly the inverse transformation was applied:

$$S(t) = e^{-e^{V(t)}}, \text{ 95\% CI: } [e(^{-e^{V(t)+2SE}}CLL^{(t)}), e(^{-e^{V(t)-2SE}}CLL^{(t)})]$$

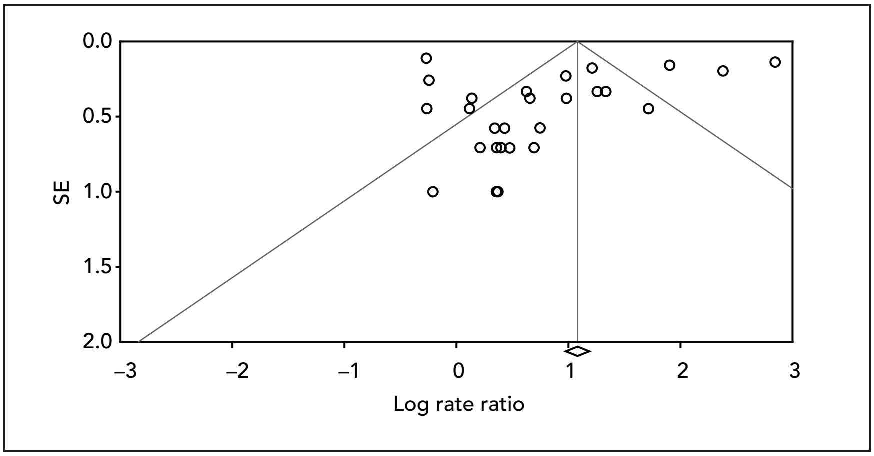

Fig 2 *Funnel plot of standard error (SE) by log rate ratio.*

The statistical analyses were performed using Comprehensive Meta-Analysis (Biostat), and the significance level was set at .05.

The risk of publications bias for this meta-analysis was evaluated through a funnel plot (Fig 2). Although the funnel plot appears to be asymmetrical, through Begg and Mazumdar rank correlation it is not possible to conclude the existence of asymmetry ($P = .34$).

Results

The initial search using the terms mentioned in the previous section led to 1,372 articles (MEDLINE [PubMed] [n = 625]; Embase [n = 1,108]; duplicates excluded [n = 361]). After applying the exclusion criteria mentioned above, a total of 29 articles[6–34] representing 23 prospective studies, 3 RCTs, and 3 retrospective studies were selected for data analysis with κ agreement scores of 0.61 for titles and 0.76 for abstracts. The total of 2,916 restorations included 52% that were prospectively analyzed, 42% that were studied retrospectively, and 5% that were analyzed in RCTs. The majority of the studied restorations (88%) were on posterior teeth (premolars and molars), while only 3% were on anterior teeth. For a high percentage (9%) of restorations, no information was given in the article on the location of the teeth (Table 3). Table 4 presents an overview of the included studies and restorations, the mean exposure time in years, *P* values, and estimated failure and survival rates for each CAD/CAM system, different type of restoration, material, and luting agent used in the selected studies.

The 2,916 restorations analyzed revealed a mean exposure time of 7.0 years. A total of 351 failures occurred, resulting in an overall survival rate of 87.5% after 5 years (95% CI: 84.5% to 90.0%). This represents a calculated failure rate of 2.17% per year, estimated per 100 restoration years (95% CI: 1.35% to 3.51%). The failure rates per study are presented in Table 3 and Fig 3, in which the weight of each of the selected studies is listed as well.

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Table 3 Descriptive and Failure Analysis: Overview of Exposure Time, Study Type, Location, and Failure Rate of Included Studies

Study	Restorations (n)	Total exposure time (y)	Study type	Tooth location	Mean exposure time (y)	Failures (n)	Estimated failure rate (per 100 restoration y) (% [CI])
Isenberg et al[6]	121	363	Pro	Posterior	3	7	1.93 (0.92–4.04)
Heymann et al[7]	42	154	Pro	Posterior	3.7	0	–
Thordrup et al[8]	30	90	Pro	Posterior	3	5	5.56 (2.31–13.35)
Molin and Karlsson[9]	20	100	Pro	Posterior	5	2	2.00 (0.50–8.00)
Pallesen and van Dijken[10]	32	256	Pro	Posterior	8	9	3.52 (1.83–6.76)
Reiss and Walther[11]	1,010	10,605	Retro	Posterior	10.5	81	0.76 (0.61–0.95)
Thordrup et al[12]	14	70	Pro	Posterior	5	1	1.43 (0.20–10.15)
Otto and De Nisco[13]	187	1,917	Pro	Posterior	10.3	15	0.78 (0.47–1.30)
Bindl and Mörmann[14]	43	140	Pro	Posterior	3.3	2	1.43 (0.36–5.72)
Reich et al[15]	54	162	Pro	Anterior and posterior	3	2	1.24 (0.31–4.94)
Sjögren et al[16]	61	610	Pro	Posterior	10	7	1.15 (0.55–2.41)
Bindl and Mörmann[17]	36	134	Pro	Anterior	3.7	2	1.49 (0.37–5.96)
Fasbinder et al[18]	71	213	Pro	Posterior	3	3	1.41 (0.45–4.37)
Bindl et al[19]	208	953	Pro	Posterior	4.6	32	3.36 (2.38–4.75)
Thordrup et al[20]	15	143	Pro	Posterior	9.5	3	2.11 (0.68–6.50)
Guess et al[21]	23	69	Pro	Posterior	3	1	1.45 (0.20–10.29)
Kokubo et al[22]	75	482	Pro	Anterior and posterior	6.4	9	1.87 (0.97–3.59)
Beuer et al[23]	50	146	Pro	Anterior and posterior	2.9	0	–
Vanoorbeek et al[24]	85	237	Pro	Anterior and posterior	2.8	9	3.80 (1.97–7.29)
Federlin et al[25]	23	124	Pro	Posterior	5.4	2	1.61 (0.40–6.44)
Kokubo et al[26]	89	445	Pro	Anterior and posterior	5	5	1.12 (0.47–2.70)
Vigolo and Mutinelli[27]	39	195	RCT	Posterior	5	3	1.54 (0.50–4.77)
Örtorp et al[28]	143	715	Retro	Posterior	5	19	2.66 (1.69–4.17)
Passia et al[29]	77	308	RCT	Posterior	4	53	17.21 (13.15–22.52)
Reich and Schierz[30]	29	123	Pro	Posterior	4.3	1	0.81 (0.11–5.76)
Klink and Huettig[31]	149	596	Pro	Anterior and posterior	4	40	6.71 (4.92–9.15)
Gherlone et al[32]	86	241	Retro	Anterior and posterior	2.8	26	10.80 (7.35–15.86)
Otto and Mörmann[33]	61	651	Pro	Posterior	10.7	5	0.77 (0.32–1.84)
Baader et al[34]	43	262	RCT	Posterior	6.1	7	2.67 (1.27–5.60)
Total summary	2,916	20,503	Pro: 52% Retro: 42% RCT: 5%	Anterior: 3% Posterior: 88% No information: 9%	7.0	351	2.17 (1.35–3.51)

CI = confidence interval; Pro = prospective; Retro = retrospective; RCT = randomized controlled trial.

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Table 4 Effects of CAD/CAM System, Restoration Type, Material Type, and Type of Luting Agent on Failures

	Restorations (n)	% of all studies	Mean exposure time (y)	*P*	Estimated failure rate[a] (per 100 restoration y) (% [CI])	Estimated survival rate after 5 years[a] (% [CI])
CAD/CAM system						
CEREC 1 (Sirona)	1,412	21	6.8	.596	1.41 (0.75–2.63)	93.2 (91.2–94.7)
CEREC 2 (Sirona)[b]	393	28	5.0	–	2.03 (1.44–2.86)	90.3 (84.9–93.9)
CEREC 3/inLab (Sirona)	502	26	5.1	.007	2.28 (1.17–4.45)	89.2 (85.4–92.1)
GN-1 (GC)	174	7	3.9	.737	2.14 (0.65–7.01)	89.9 (79.6–95.1)
Procera (Nobel Biocare)	237	9	5.5	.135	2.36 (1.65–3.37)	88.9 (82.0–93.2)
Lava (3M ESPE)	106	5	3.9	< .001	4.02 (0.40–40.02)	81.8 (70.7–89.0)
KaVo ARCTICA	77	3	4.0	< .001	17.21 (13.15–22.52)	42.3 (27.3–56.5)
Celay (Mikrona)	15	2	3.0	.161	6.67 (2.15–20.67)	71.6 (18.0–93.7)
Restoration type						
Core crown	553	26	3.8	.092	2.63 (1.25–5.56)	87.7 (83.0–91.2)
Crown	360	17	5.1	< .001	2.61 (0.99–6.89)	87.8 (83.8–90.8)
Inlay/onlay[b]	1,826	51	5.8	–	1.91 (1.14–3.21)	90.9 (88.8–92.6)
Endocrown	120	4	6.1	< .001	2.56 (0.62–10.50)	88.0 (79.1–93.2)
Reduced crown	54	2	3.8	.368	2.93 (1.40–6.14)	86.4 (65.2–95.1)
Veneer	3	1	3.0	.829	–	–
Material type						
Glass-matrix ceramic	2,324	74	5.6	< .001	1.79 (1.14–2.80)	91.4 (89.8–92.8)
Polycrystalline ceramic[b]	521	22	4.1	–	4.07 (1.69–9.81)	81.6 (76.7–85.6)
Resin-matrix ceramic	71	3	2.9	.046	3.85 (1.16–12.77)	82.5 (59.2–93.2)
Luting agent						
Chemically cured	460	22	5.0	< .001	2.81 (0.92–8.62)	86.9 (82.6–90.2)
Light-cured	654	26	6.1	.274	1.94 (1.13–3.32)	90.8 (87.5–93.2)
Dual-cured[b]	1,802	52	5.4	–	2.24 (1.17–4.29)	89.4 (87.1–91.3)
Summary	2,916	100	7.0	–	2.17 (1.35–3.51)	89.7 (88.1–91.1)

[a]Based on random effects.
[b]Reference variable.

Among the CAD/CAM systems used, the KaVo ARCTICA system (*P* < .001; 17.21%) and the Lava (3M ESPE) system (*P* < .001; 4.02%) showed significantly higher failure rates compared to CEREC 2 (Sirona) (2.03%), while the other CAD/CAM systems did not differ significantly (Table 4).

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Study	Rate ratio	Lower limit	Upper limit	Relative weight
Isenberg et al[6]	1.93	0.92	4.04	3.98
Thordrup et al[8]	5.56	2.31	13.35	3.84
Molin and Karlsson[9]	2.00	0.50	8.00	3.21
Pallesen and Van Dijken[10]	3.52	1.83	6.76	4.07
Reiss and Walther[11]	0.76	0.61	0.95	4.37
Thordrup et al[12]	1.43	0.20	10.15	2.53
Otto and De Nisco[13]	0.78	0.47	1.30	4.20
Bindl and Mörmann[14]	1.43	0.36	5.72	3.22
Reich et al[15]	1.24	0.31	4.94	3.22
Sjögren et al[16]	1.15	0.55	2.41	3.98
Bindl and Mörmann[17]	1.49	0.37	5.96	3.21
Fasbinder et al[18]	1.41	0.45	4.37	3.53
Bindl et al[19]	3.36	2.38	4.75	4.31
Thordrup et al[20]	2.11	0.68	6.52	3.54
Guess et al[21]	1.45	0.20	10.29	2.53
Kokubo et al[22]	1.87	0.97	3.59	4.07
Vanoorbeek et al[24]	3.80	1.97	7.29	4.07
Federlin et al[25]	1.61	0.40	6.46	3.21
Kokubo et al[26]	1.12	0.47	2.70	3.84
Vigolo and Mutinelli[27]	1.54	0.50	4.77	3.53
Örtorp et al[28]	2.66	1.69	4.17	4.24
Passia et al[29]	17.21	13.15	22.52	4.34
Reich and Schierz[30]	0.81	0.11	5.76	2.53
Klink and Huettig[31]	6.71	4.92	9.15	4.33
Gherlone et al[32]	10.80	7.35	15.86	4.28
Otto and Mörmann[33]	0.77	0.32	1.84	3.84
Baader et al[34]	2.67	1.27	5.61	3.98
	2.17	1.35	3.51	3.98

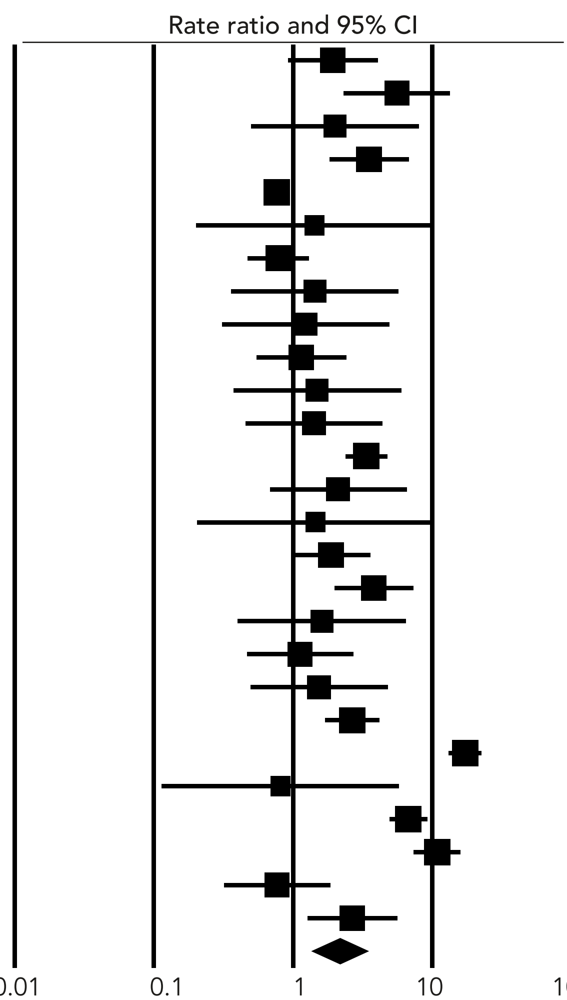

Fig 3 *Forest plot: random effects of failure rates, confidence intervals (CI), and weight of each study.*

Glass-matrix ceramic restorations exhibited a much lower failure rate than polycrystalline ceramic ($P < .001$; 1.79% vs 4.07%), and resin-matrix ceramic restorations showed significantly higher failure rates compared to polycrystalline ceramic ($P < .046$; 3.85% vs 4.07%) (Table 4).

Regarding type of restoration, endocrowns ($P < .001$; 2.56%) and crowns ($P < .001$; 2.61%) revealed a significantly higher failure rate than inlays/onlays (1.91%), while the other restoration types did not differ significantly. Chemically cured restorations had a higher failure rate when compared to dual-cured restorations ($P < .001$; 2.81% vs 2.24%). Outcomes with light-cured restorations were not statistically significant (Table 4).

Discussion

Despite the advantages of CAD/CAM technology in fabricating indirect restorations, the driving forces for treatment success are good clinical judgment and skills along with selection of the appropriate material and fabricating process. With any manufacturing process, it is important to respect its various phases for long-term performance objectives.

The introduction of new technologies, manufacturing processes, and materials in dental clinical practice should ideally be supported by scientific evidence. However, literature research reveals the existence of very few well-controlled investigations, such as RCTs, on these issues.[35]

The aim of this investigation was to conduct a systematic review

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of the performance of single-tooth restorations fabricated with CAD/CAM technology. It also sought to underscore the absence of robust evidence to support the routine use of well-accepted dental restorative treatment protocols.

Specifically, this systematic review evaluated the long-term clinical survival rate of single-tooth restorations fabricated with CAD/CAM technology reported in carefully selected investigations. As expected, only 3 of the 29 studies included are RCTs. This confirms that few studies address this issue with a protocol design covering control groups and random patient selection. This raises concerns regarding clinicians' ability to make evidence-based decisions regarding CAD/CAM restorations.[36] Other limitations included differences in study design, authors, and the weight of each investigation (Fig 3).

Of the literature included in this systematic review, the research of Reiss and Walther[11] reporting long-term clinical results of restorations made with the CEREC system presented the greatest scientific relevance (Fig 3). Consequently, the study had an effect on the statistical analysis (weight = 4.37%).

Failure analysis in each study was based on different criteria systems: United States Public Health Service criteria (17 studies), California Dental Association criteria (9 studies), and criteria defined by the authors themselves (3 studies). In this systematic review, the effect on failure was assessed by the CAD/CAM system used, the type of restoration, the restoration material, and the luting agent.

The CAD/CAM systems used in the selected studies were CEREC 1 (Sirona), CEREC 2 (Sirona), CEREC 3/inLab (Sirona), GN-1 (GC), Procera (Nobel Biocare), Lava (3M ESPE), KaVo ARCTICA, and Celay (Mikrona). KaVo ARCTICA ($P < .001$) and Celay ($P < .001$) had the highest failure rate when compared to the CEREC 2 system. Survival rates after 5 years in function differed: 93.2% for CEREC 1, 93.0% for Celay, 90.3% for CEREC 2, 89.9% for GN-1, 89.2% for CEREC 3/inLab, 88.9% for Procera, 81.8% for Lava, and 42.3% for KaVo ARCTICA. The study by Passia et al[29] was the only article included in this systematic review that used the KaVo ARCTICA system to mill ceramic blocks of $ZrSiO_4$ for the rehabilitation of posterior teeth. They concluded, however, that the use of ZrSiO4 ceramic crowns in posterior teeth is not recommended. This may be the justification for the high failure rate obtained by the KaVo ARCTICA system.

Regarding the restoration type, crowns ($P < .001$; 2.61%) and endo crowns (crowns that extend into the pulp chamber as one piece) ($P < .001$; 2.56%) had a significantly higher failure rate than all other investigated restorations when compared with inlay/onlay restorations. Inlay/onlay restorations had a higher 5-year survival rate (90.9%), while reduced crowns had the lowest (86.4%). The survival rates after 5 years for core crown (87.7%), crown (87.8%), and endo crown (88.0%) restorations were quite similar.

According to Land and Hopp[37] restorations that require less reduction of dental structure, such as inlays/onlays, present similar clinical results to total covering crowns. In this systematic review, the inlays/onlays (90.9%; 95% CI: 88.8% to 92.6%) presented a survival rate after 5 years in clinical function superior to the one obtained by total crowns (87.8%; 95% CI: 83.8% to 90.8%), suggesting that more conservative dental interventions result in greater clinical performance. Concordant results were obtained by Belli et al[38] in their study of inlays/onlays and total crown restorations made in IPS e.max CAD blocks (lithium disilicate, Ivoclar Vivadent).

The lowest survival rate was obtained with crowns made on reduced preparations (86.4%). Similar results were obtained by Bindl et al[19] that reported survival rates of 92.9% and 92.1% for reduced crowns on premolars and molars, respectively, and a survival rate for endocrowns of 68.8% for premolars and 87.1% for molars.

The results regarding the type of material showed a low failure rate for glass-matrix ceramics compared to polycrystalline ceramics ($P < .001$; 1.79% vs 4.07%). The highest 5-year survival rate was obtained by glass-matrix ceramics (91.4%), followed by resin-matrix ceramics (82.5%) and polycrystalline ceramics (81.6%). The results by type of ceramic showed that resin-matrix ceramics (3.85%; 95% CI: 1.16% to 12.77%) and polycrystalline ceramics (4.07%; 95% CI: 1.69% to 9.81%) had the highest failure rates. Recently, Ankyu et al[39] concluded in their in vitro study on the fatigue analysis of resin-matrix ceramic crowns that this ceramic material has potential for clinical ap-

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plication in terms of the fatigue resistance parameter.

All failures of polycrystalline ceramic restorations were on posterior teeth and were mostly fabricated in $ZrSiO_4$. The high percentage of $ZrSiO_4$ posterior crowns can, as already mentioned, justify the high failure rate obtained by polycrystalline ceramics.

Belli et al[38] described a trilayer system, IPS e.max CAD on ZrO_2, composed of a machined lithium disilicate overlay (IPS e.max CAD) and a ZrO_2 framework, which after being separately sintered are fused together using a fusion glass layer. In their study, they concluded that this system presented significantly better clinical results when compared to monolithic IPS e.max CAD (glass-matrix ceramic) restorations ($P = .0023$).

Luting agent type evaluation showed that chemically cured restorations had a higher failure rate compared to dual-cured restorations ($P < .001$; 2.81% vs 2.24%).

Dual luting agents have been recommended for ceramic and resin-matrix ceramic inlays to compensate for the obstacle that the restoration itself is to light transmission, and to allow complete polymerization of the luting agent even at the bottom of the cavity, where the access of LED curing light is limited.[40] Hofmann et al,[40] in their comparative study of flexural strength, modulus of elasticity, and surface hardness of several chemically, light-, and dual-curing cements concluded that dual-curing cements produced better mechanical properties than light-curing cements. Although the present results do not agree with those of Hofmann et al,[40] the study protocol did not evaluate the polymerization contraction of the different types of cement under different polymerization conditions, or the importance of compliance with the manufacturer's guidelines for selection and use of the different types of cement.

Of 2,916 restorations in clinical function for a mean exposure time of 7.0 years, 351 failures were obtained, leading to an estimated failure rate of 2.17% per 100 restoration years (95% CI: 1.35% to 3.51%). The overall survival rate after 5 years in clinical function was 87.5% (95% CI: 84.5% to 90.0%).

Wittneben et al[41] presented in their systematic review study very similar results: an estimated failure rate of 1.75% per year (95% CI: 1.22% to 2.52%) and an overall survival rate after 5 years in clinical function of 91.6% (95% CI: 88.2% to 94.1%).

In their systematic review on single crowns, Pjetursson et al[42] reported an overall survival rate after 5 years in clinical function of 93.3% (95% CI: 91.1% to 95%) for ceramic crowns and 95.6% (95% CI: 92.4% to 97.5%) for metal-ceramic crowns, which reveals the similarity of the clinical results of crowns produced by CAD/CAM systems when compared with crowns made by conventional techniques.

Boitelle et al[43] carried out a systematic review on the fit of restorations made by CAD/CAM systems. They concluded that it is possible to obtain a gap smaller than 80 μm between the dental structure and the surface of the CAD/CAM restoration. This means that CAD/CAM systems achieve values of prosthetic structure adaptation relatively lower than conventional manufacturing methods.

Recently, Morimoto et al,[44] in a systematic review of the survival rate of inlays/onlays/overlays, reported a estimated survival rate of 91% after 10 years in function for glass-ceramics and feldspathic porcelain restorations produced by CAD/CAM technology.

Conclusions

A lack of studies using a randomization protocol was identified for this particular treatment topic. Nonetheless, the relevant and selected literature reveals an overall survival rate of 87.5% after 5 years (95% CI: 84.5% to 90.0%) and an estimated failure rate of 2.17% (95% CI: 1.35% to 3.51%). Additional findings include the following: *(1)* KaVo ARCTICA ($P < .001$; 17.21%) and Lava ($P < .001$; 4.02%) had a higher failure rate when compared to CEREC 2 (2.03%); *(2)* glass-matrix ceramic restorations ($P < .001$; 1.79%) and resin-matrix restorations ($P = .046$; 3.85%) showed a lower failure rate when compared to polycrystalline ceramic restorations (4.07%); *(3)* full-coverage crowns ($P < .001$; 2.61%) and endo crowns ($P = .001$; 2.56%) showed a higher failure rate when compared to inlay/onlay restorations (1.91%); and *(4)* chemically cured restorations ($P < .001$; 2.81%) showed a higher failure rate when compared to dual-cured restorations (2.24%).

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