A Systematic Review and Meta-analysis Evaluating the Survival, Failure, and Complication Rates of Metal-Ceramic, Veneered, and Monolithic All-Ceramic Tooth-Supported Single Crowns—Part 1

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Purpose: To evaluate 5-year survival rates of metal-ceramic, veneered all-ceramic, and monolithic all-ceramic tooth-supported single crowns (SCs) and assess biologic and technical complications. ***Materials and Methods:*** A systematic search was conducted using MEDLINE (PubMed), Embase, and CENTRAL for prospective clinical studies published between 2014 and 2024, focused on tooth-supported fixed dental prostheses (FDPs; ≥ 3 years mean follow-up). In addition, 30 studies identified from previous reviews were included through manual screening. ***Results:*** A total of 64 studies met the inclusion criteria, reporting on 3,509 metal-ceramic and 8,051 all-ceramic SCs. Robust Poisson regression models were used to estimate pooled 5-year survival and complication rates. In total, 12 prospective clinical studies reported exclusively on metal-ceramic crowns, 49 investigated all-ceramic crowns, and 3 investigated both. The estimated 5-year survival rates were the following: 98.5% for monolithic lithium disilicate–reinforced glass-ceramic SCs, 97.3% for veneered densely sintered zirconia SCs, 97.1% for metal-ceramic SCs, 96.8% for monolithic densely sintered zirconia SCs, 95.7% for veneered leucite or lithium disilicate–reinforced glass-ceramic SCs, 94.5% for densely sintered alumina SCs, 94.3% for glass-infiltrated alumina SCs, and 90.4% for feldspathic/silica-based ceramic SCs. The survival rates of feldspathic/silica-based ceramic ($P < .0001$), glass-infiltrated alumina ($P = .019$), densely sintered alumina ($P = .002$), and veneered leucite or lithium disilicate–reinforced glass-ceramic SCs ($P = .021$) were significantly lower than that of the monolithic lithium disilicate SCs. Except for feldspathic/silica-based ceramic and metal-ceramic crowns, material/design types performed similarly in anterior and posterior regions. Monolithic lithium disilicate–reinforced glass-ceramic and monolithic densely sintered zirconia crowns showed significantly lower rates of ceramic fractures and surface chipping compared to traditionally veneered metal-ceramic and all-ceramic SCs. ***Conclusions:*** Monolithic lithium disilicate–reinforced glass-ceramic and monolithic densely sintered zirconia all-ceramic SCs achieve 5-year survival rates comparable to those of metal-ceramic crowns. Monolithic designs reduce the incidence of fracture and chipping risk, improving long-term clinical outcomes. *Int J Prosthodont 2026;39:308–324. doi: 10.11607/ijp.9633*

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Tooth-supported single crowns (SCs) are a relevant fixed-prosthodontics treatment option indicated for the reconstruction of structurally compromised teeth in which the replacement of extensive tooth substance loss cannot be done with less invasive adhesive reconstructions (eg, onlays, partial crowns, veneers). Historically, metal-ceramic crowns have been regarded as the clinical gold standard due to their well-documented longevity, mechanical reliability, and acceptable esthetic outcomes.[1] However, the increasing demand for more natural esthetic, metal-free restorations, combined with advancements in ceramic material science, has led to a pronounced shift in clinical practice toward the use of all-ceramic crowns in the last decades. Current literature supports that the current all-ceramic systems can offer survival rates comparable to those of metal-ceramic crowns, even in posterior load-bearing regions, while additionally fulfilling patient expectations for natural appearance and biocompatibility.[2–5]

Several factors have contributed to the expanded use of all-ceramic crowns in recent years. Beyond esthetics, the rising cost and limited availability of high-noble metals, along with the adoption of digital workflows and adhesive bonding techniques, have further led to the increasing use of ceramic-based reconstructions. The development of high-strength ceramics, such as lithium disilicate and yttria-stabilized zirconia, has addressed the mechanical limitations of earlier generations of glass-ceramics (eg, feldspathic and leucite-reinforced ceramics), which were primarily indicated for anterior regions due to their low fracture resistance.[1]

With the evolution of CAD/CAM technologies,[6] further improved dental ceramics were introduced, such as recent versions of lithium disilicate/silicate ceramics and a large variety of zirconia ceramics. These materials can be applied monolithic due to their improved esthetics, or with a buccal microveneering in cases with high esthetic needs. Recent systematic reviews showed good outcomes of the monolithic zirconia and lithium disilicate ceramic.[7,8]

Moreover, these more recent materials have demonstrated enhanced flexural strength and fracture toughness, thereby expanding the indications of all-ceramic crowns to include posterior SCs and even multi-unit fixed dental prostheses (FDPs).[9]

Subsequent clinical studies have confirmed that these more recent ceramic materials perform significantly better than their predecessors in tooth-supported restorations. Systematic reviews have demonstrated notably higher survival rates for crowns fabricated from reinforced ceramics, such as leucite or lithium disilicate, compared to those made from feldspathic ceramics.[4,5] Among all-ceramic materials, densely sintered alumina and zirconia showed the highest survival rates. Moreover, survival rates of all-ceramic SCs were found to be similar to those of metal-ceramic crowns.[4,5]

As a result, the long-standing paradigm that metal-ceramic crowns are the preferred option for posterior restorations is nowadays being challenged. It is increasingly reasonable to question whether metal-ceramic restorations still represent the benchmark in tooth- and implant-supported crown therapy, given the clinical success, esthetic superiority, and evolving material science supporting all-ceramic alternatives.

To address this current challenge, the aim of the present systematic review was to analyze the outcomes of the all-ceramic and metal-ceramic SCs, and to assess whether current all-ceramic systems achieve similar long-term outcomes as the metal-ceramics.

The objectives of this systematic review were the following:

1. To update the previous systematic reviews[4,5] on tooth-supported all-ceramic SCs and metal-ceramic SCs with an additional literature search of controlled and prospective studies.
2. To obtain overall robust estimates of the long-term survival and complication rates of all-ceramic SCs and metal-ceramic SCs over an observation period of at least 5 years.
3. To compare the survival and complication rates of all-ceramic SCs with those of metal-ceramic SCs to assess if metal-ceramic is still the gold standard.

MATERIALS AND METHODS

This systematic review is reported in accordance with the Preferred Reporting Items for Systematic review and Meta-Analysis (PRISMA) 2020 guidelines.[10] A comprehensive protocol was developed and registered in PROSPERO (CRD42021277877).

Focused Questions

According to the previous publications,[4,5] this systematic review aimed to answer the following focused question: What are the estimated survival and complications rates of metal-ceramic and all-ceramic tooth-supported SCs after an observation period of 5 years?

Inclusion and Exclusion Criteria

The inclusion criteria for this systematic review were defined according to the PICOS acronym:

- (P) Population: Subjects with anterior and/or posterior tooth-supported SCs with at least 3 years of function
- (I) Intervention: All-ceramic tooth-supported SCs
- (C) Comparison: Metal-ceramic tooth-supported SCs
- (O) Outcomes: Survival rates and technical and/or biologic complication rates
- (S) Study design: Randomized controlled clinical trials (RCTs) and prospective cohort studies

Only studies published in English were included in the literature search performed for this systematic review.

Additional inclusion criteria for study selection were the following:

- Studies with a minimum mean follow-up period of 3 years.
- Patients had to be clinically examined at follow-up visits (ie, studies based solely on patient records, questionnaires, or interviews were excluded).
- Studies had to report details on the characteristics of the reconstructions, materials, methods, and results.
- Studies had to include at least 10 patients.
- Only studies published in English language were considered.

Search Strategy

Two of the review authors (P.R., A.B.) independently screened titles and abstracts in duplicate across three different databases (PubMed, Embase, Cochrane Central Register of Controlled Trials [CENTRAL]) for studies published between January 1, 2014 and December 4, 2024. The detailed search strategy for the electronic screening is reported in Appendix Box 1 (appendix items are available in the online version of this article). Any disagreements were resolved through discussion, or if resolution was not achieved, a third review author was consulted (J.P.) to make the final decision. The same review authors also conducted in duplicate the full-text analysis of all the included studies selected during the screening process and determined their inclusion in the systematic review. Reasons for exclusion were recorded. When multiple studies reported results from the same cohort, only the study with the longest follow-up period was included. Additionally, 30 studies from previous systematic reviews on tooth-supported SCs by Pjetursson et al[1] and Sailer et al[5] were considered for incorporation in this updated review. The previous review covered a literature search until the end of 2013.

Data Extraction

After calibration, data from the included studies were extracted in duplicate by three review authors (P.R., B.E.P., G.R.B.) using predefined data extraction forms. Any disagreements were resolved through discussion.

For each study, the following data were extracted: author(s), year of publication, study design, study setting, initial number of patients, age (mean and range), actual number of patients at end of study, overall drop-out rate, reported follow-up time (mean), reported survival rate, initial number of SCs, location (anterior/posterior), framework material, brand name of framework material, manufacturing procedures, veneering material, type of cement, number of SCs failed (anterior vs posterior), reported biologic complications (total number of biologic complications, caries on abutments, SCs lost to caries, endodontic complications, SCs lost due to endodontic failures, and SCs lost due to abutment tooth fracture), reported technical complications (total number of technical complications, total number of ceramic chippings or fractures, failure due to core fracture, minor ceramic chippings what could be polished, major ceramic chippings that needed repair, failure due to catastrophic veneering ceramic fracture, and loss of retention), SCs remade due to esthetic issues, and marginal discoloration.

After data extraction, all the restoration materials were categorized based on their framework material and design (monolithic vs veneered restorations). For meta-analytic purposes, monolithic and microveneered restorations were combined in the same group.

Quality Assessment of the Included Studies

Quality assessment and risk of bias evaluation were independently performed during the data extraction phase, employing the newly developed Quality-Assessment-Scale for Reconstructive Studies (QAS-RS), which has been specifically developed for prospective and retrospective clinical medical or dental reconstructive studies by the authors of this review. This scale encompasses seven methodologic domains: *(1)* appropriateness of sample size determination, *(2)* frequency of follow-up assessments, *(3)* adequacy of inclusion and exclusion criteria, *(4)* methods of outcome assessment, *(5)* quality of reporting on failures and complications, *(6)* duration of follow-up, and *(7)* drop-out rate throughout follow-up (Appendix Box 2). Similar to other quality assessment scales in the literature,[11–13] the QAS-RS employs a star system, with each domain rated on four different levels corresponding to values from 0 to 3 stars. The overall quality assessment of the included studies was categorized as low (0 to 7 stars), moderate (8 to 14 stars), or high (15 to 21 stars; see Appendix Box 2).

Data Analysis

In the present systematic review, failure and complication rates were calculated by dividing the number of events (failures or complications) in the numerator by the total restoration or abutment tooth exposure time in the denominator.

The numerator could usually be extracted directly from the publication. The total exposure time was calculated by taking the sum of the following:

- Exposure time of restorations that could be followed for the whole observation time.
- Exposure time up to a failure of the restorations that were lost during the observation time.

- Exposure time up to the end of observation time for restorations in patients that were lost to follow-up due to reasons such as death, change of address, refusal to participate, non-response, chronic illnesses, missed appointments, and work commitments.

For each study, event rates for the restorations were calculated by dividing the total number of events by the total restorations exposure time in years. For further analysis, the total number of events was considered to be Poisson distributed for a given sum of restoration exposure and Poisson regression were used with a logarithmic link-function and total exposure time per study as an offset variable.[14,15] To assess heterogeneity of the study specific event rates, Spearman goodness-of-fit statistics and the associated *P* values were calculated. To reduce the effect of heterogeneity Robust standard errors were calculated to obtain 95% CIs of the summary estimates of the event rates.

The 5-year failure/complication proportions were calculated via the relationship between event rate and failure/complication function *F:* $F(T) = \exp(-T \times \text{event rate})$ by assuming constant event rates.[14,15]

The 95% CIs for the failure/complication proportions were calculated using the 95% confidence limits of the event rates. Multivariable Poisson regression was used to investigate formally whether event rates varied by the material used. All analyses were performed using Stata, version 15.1 (Stata).

Additionally, subgroup meta-analyses were performed based on location (anterior vs posterior) to evaluate overall annual failure rates and estimated 5-year survival for all included restoration materials. Further subgroup analyses were conducted based on crown design (monolithic/microveneered vs veneered) to assess the overall annual failure rates and individual complication rates limited to reinforced glass-ceramic and zirconia restorations.

RESULTS

Study Selection Process

A total of 3,310 articles were retrieved from the electronic search: 1,631 from PubMed, 1,357 from Embase, and 322 from the Cochrane Central Register of Controlled Trials (CENTRAL). After removing duplicates, 2,043 remained for the screening of titles and abstracts. Finally, 146 studies underwent to the full-text analysis and a total of 34 studies were included. All reasons for exclusion are reported in the Appendix Table 1. Additionally, 30 studies published before 2015 were identified from the previous systematic reviews on the same topic.[1,5] After the inclusion process, a total of 64 studies were included (Fig 1).

Characteristics of the Included Studies

A total of 64 studies were included, reporting 84 patient cohorts and 11,560 restorations. Of these, 19 were RCTs, and 45 were prospective cohort studies. Retrospective studies were excluded from the present systematic review.

Nine distinct restorative material/design categories were identified: metal-ceramic (16 cohorts),[16–30] glass-ceramic (feldspathic/silica-based; 6 cohorts),[31–36] veneered reinforced glass-ceramic (10 cohorts),[34,37–45] monolithic reinforced glass-ceramic (11 cohorts),[37,38,40,46–53] glass-infiltrated alumina (8 cohorts),[32,34,35,54–58] densely sintered alumina (5 cohorts),[59–63] veneered densely sintered zirconia (17 cohorts),[20,25,27,51,52,64–74] monolithic or micro-veneered densely sintered zirconia (10 cohorts),[47–50,75–78] and zirconia silicate (1 cohort).[79] Research interest in glass-infiltrated alumina SCs and densely sintered alumina SCs appears to have diminished, represented by the absence of published studies on the former since 2014 and on the latter since 2010.

Among the 19 RCTs, 10 involved direct comparisons between different restorative designs. Specifically, 2 RCTs compared metal-ceramic to zirconia-ceramic SCs[20,27]; 5 studies compared reinforced glass-ceramic with zirconia-ceramic SCs[47,49–52]; 1 compared glass-ceramic with glass-infiltrated alumina[32]; 1 RCT compared veneered vs monolithic reinforced glass-ceramic[37]; and 1 study simultaneously compared metal-ceramic, monolithic zirconia-ceramic and partially veneered zirconia-ceramic SCs.[48] The remaining 9 RCTs investigated outcomes beyond the scope of this systematic review.

Regarding the scope of material evaluation, 3 studies investigated three distinct material/design groups,[27,34,48] 14 studies assessed two material/design,[20,25,28,32,35,37,38,40,47,49–52,77] while the remaining 47 studies focused on a single material cohort.[16–19,21–24,26,29–31,33,36,39,41–43,45,46,53–76,78,79] A detailed overview of the included studies is presented in Appendix Table 2.

Survival and Failure Rates

In total, 15 studies, with a mean follow-up period of 9.6 years, reported on the survival of 3,509 metal-ceramic SCs. The estimated annual failure rate was 0.59%, corresponding to a 5-year survival rate of 97.1%. Comparatively, all-ceramic SCs exhibited annual failure rates ranging from 0.29% to 2.02%, resulting in 5-year survival rates between 90.4% and 98.5% (Table 1).

Among all-ceramic single SCs, the highest survival rate was observed for monolithic reinforced glass-ceramic SCs. A total of 11 studies, encompassing 1,106 monolithic lithium disilicate–reinforced glass ceramic SCs, reported an annual failure rate of 0.29%, equating to a 5-year survival rate of 98.5%. Veneered densely sintered zirconia SCs exhibited the second-lowest annual failure rate (0.55%), corresponding to a 5-year survival

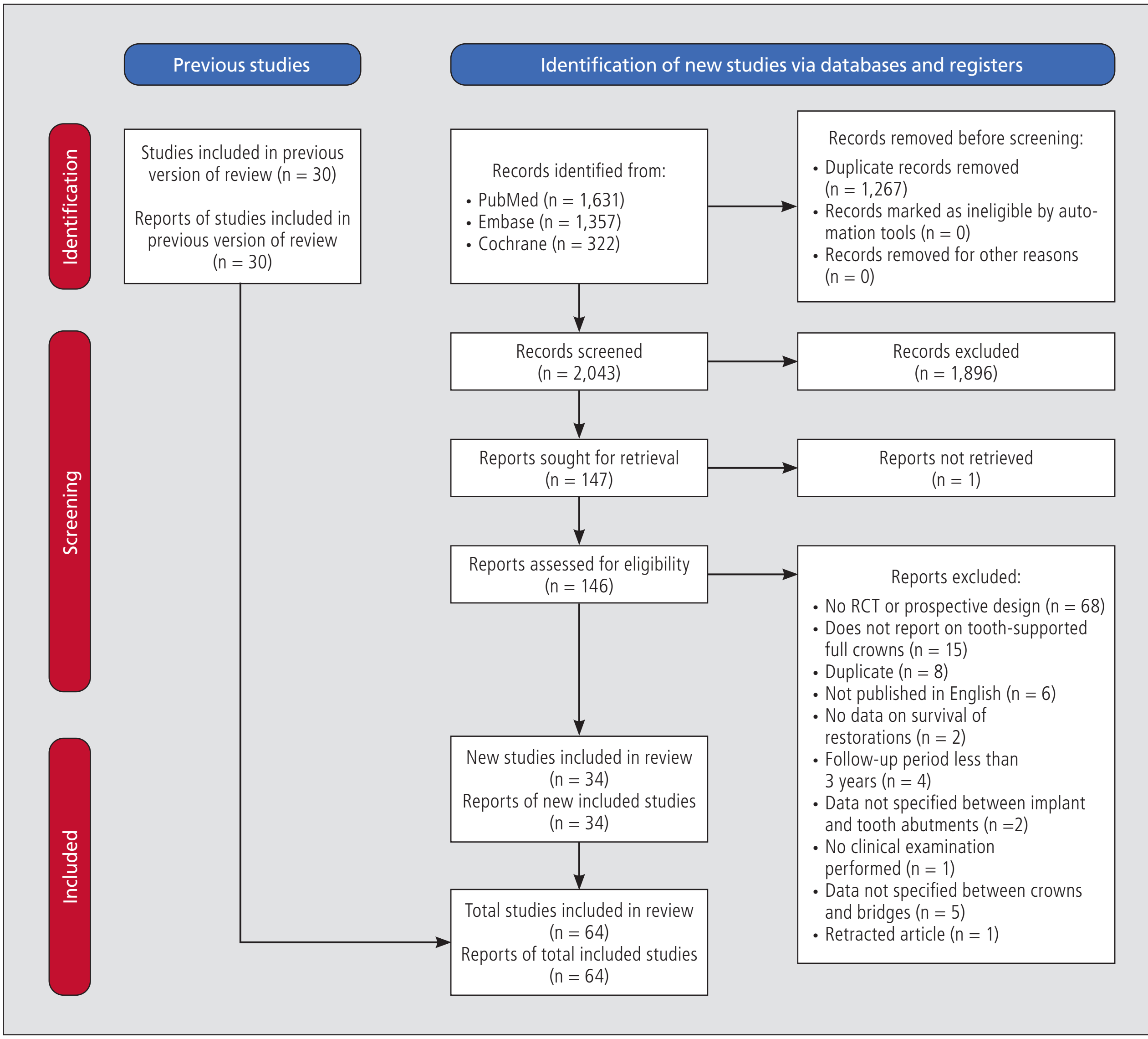

Fig 1 PRISMA 2020 flow diagram for updated systematic reviews, which included searches of databases and registers only.

rate of 97.3%. Other survival estimates included monolithic densely sintered zirconia SCs with a 0.66% annual failure rate translating into a 5-year survival of 96.8% and veneered leucite/lithium disilicate–reinforced glass-ceramic SCs with an annual failure rate of 0.88% and a 5-year survival of 95.7%. Feldspathic/silica-based ceramic SCs, demonstrated the highest annual failure rate (2.02%) translating into a 5-year survival rate of 90.4%. The second highest annual failure rate of 1.18% equating to a 5-year survival of 94.3% was estimated for glass-infiltrated alumina SCs and the third highest annual failure rate (1.13%) resulting in a 5-year survival of 94.5% was estimated for densely sintered alumina SCs.

A multivariable Poisson regression analysis performed to compare the survival rates between different types of all-ceramic SCs and metal-ceramic SCs with metal-ceramic as a reference revealed that feldspathic/silica ceramic SCs ($P < .0001$), densely sintered alumina SCs ($P = .005$), and glass-infiltrated alumina SCs ($P = .006$) had significantly lower survival rates. No significant differences were observed for other types of ceramic SCs when compared with metal-ceramic SCs (Appendix Table 3).

In addition, a multivariable Poisson regression analysis was conducted to evaluate the survival rates of various SC types, using monolithic lithium disilicate–reinforced glass-ceramic single SCs which had the best outcome as reference. Compared to the monolithic lithium disilicate glass-ceramic SCs, significantly lower survival rates were observed for feldspathic/silica-based ceramic SCs ($P < .0001$), densely sintered alumina SCs ($P = .002$), glass-infiltrated alumina SCs ($P = .019$), and veneered reinforced glass-ceramic SCs ($P = .021$).

Table 1 Annual Failure Rates and Survival of Metal-Ceramic and All-Ceramic SCs

Study	Year of publication	Total no. of SCs	Calculated mean exposure time (years)	No. of failures	Total SC exposure time, years	Estimated annual failure rate* (per 100 SCs)	Estimated survival after 5 years*
Metal-ceramic							
Poletto-Neto et al[16]	2024	34	8.0	3	272	1.10	94.6%
Bacher et al[17]	2021	31	8.5	4	262	1.53	92.7%
Chaar et al[18]	2020	60	10.5	6	630	0.95	95.3%
Brondani et al[19]	2017	152	2.8	6	419	1.43	93.1%
Monaco et al[20]	2017a	45	4.5	1	204	0.49	97.6%
Ohlmann et al[21]	2014	40	4.0	5	160	3.13	85.5%
Hey et al[22]	2014	41	5.7	3	234	1.28	93.8%
Tao et al[23]	2014	100	2.7	14	270	5.19	77.2%
Reitemeier et al[24]	2013	190	9.6	10	1832	0.55	97.3%
Rinke et al[25]	2013a	50	3.0	1	146	0.68	96.6%
Walton[26]	2013	2,340	11.6	133	27,272	0.49	97.6%
Vigolo and Mutinelli[27]	2012a	20	4.8	0	95	1.14	94.5%
Naumann et al[28]	2011a	52	3.4	2	176	0	100%
Naumann et al[28]	2011b	52	3.4	0	176	0	100%
Gungor et al[29]	2007	260	5.4	7	1400	0.50	97.5%
Marklund et al[30]	2003	42	4.5	3	190	1.58	92.4%
Total		3,509	9.6	198	33,738		
Summary estimate (95% CI)						0.59 (0.43–0.80)	97.1% (96.1%–97.9%)
Feldspathic/silicaceramic							
Fages et al[31]	2017	212	4.5	5	953	0.52	97.4%
Çehreli et al[32]	2011a	50	3.3	3	165	1.82	91.3%
Burke[33]	2007	59	3.2	3	187	1.60	92.3%
Malament and Socransky[34]	2006a	1,061	7.9	177	8,407	2.11	90.0%
Bindl and Mörmann[35]	2004a	18	3.7	1	67	1.49	92.8%
Kelsey et al[36]	1995	101	3.8	16	388	4.12	81.4%
Total		1,501	6.8	205	10,167		
Summary estimate (95% CI)						2.02 (1.67–2.44)	90.4% (88.5%–92.0%)
Reinforced glass-ceramic, veneered							
Spehar and Jakovac[37]	2024a	26	3.0	0	78	0	100%
Margvelashvili-Malament et al[38]	2024a	264	7.2	0	1,912	0	100%
Teichmann et al[39]	2017a	106	9.4	22	992	2.22	89.5%
Huettig and Gehrke[40]	2016a	202	3.0	3	495	0.61	97.0%
Toman and Toksavul[41]	2015	125	8.4	10	1,055	0.95	95.4%
Gehrt et al[42]	2013	104	6.0	4	623	0.64	96.8%
Malament and Socransky[34]	2006b	954	3.9	33	3,732	0.88	95.7%
Marquardt and Strub[43]	2005	27	3.9	0	105	0	100%
Sorensen et al[44]	1998	75	3.0	1	224	0.45	97.8%

Table 1 Annual Failure Rates and Survival of Metal-Ceramic and All-Ceramic SCs *(cont)*

Study	Year of publication	Total no. of SCs	Calculated mean exposure time (years)	No. of failures	Total SC exposure time, years	Estimated annual failure rate* (per 100 SCs)	Estimated survival after 5 years*
Reinforced glass-ceramic, veneered (cont)							
Studer et al[45]	1998	142	5.0	14	710	1.97	90.6%
Total		2,025	4.9	87	9,926		
Summary estimate (95% CI)						0.88 (0.51–1.51)	95.7% (92.7%–97.5%)
Reinforced glass-ceramic, monolithic							
Spehar and Jakovac[37]	2024b	26	3.0	1	75	1.33	93.6%
Margvelashvili-Malament et al[38]	2024b	287	7.8	4	2,231	0.18	99.1%
Rauch et al[46]	2023	34	12.5	6	424	1.42	93.2%
Hammoudi et al[47]	2022a	362	2.7	1	987	0.10	99.5%
Le et al[48]	2022a	30	3.1	0	94	0	100%
Kasem et al[49]	2022a	20	3.0	0	60	0	100%
Gardell et al[50]	2021a	29	3.4	0	100	0	100%
Seidel et al[51]	2020a	15	2.9	0	44	0	100%
Lundgren et al[52]	2018a	108	5.5	1	594	0.17	99.2%
Huettig and Gehrke[40]	2016b	173	3.0	1	424	0.24	98.8%
Cortellini and Canale[53]	2012	22	3.5	1	78	1.28	93.8%
Total		1,106	4.6	15	5,111		
Summary estimate (95% CI)						0.29 (0.13–0.66)	98.5% (96.8%–99.3%)
Glass-infiltrated alumina							
Çehreli et al[32]	2011b	51	3.4	2	172	1.16	94.4%
Kokubo et al[54]	2011	101	4.6	7	464	1.51	92.7%
Malament and Socransky[34]	2006c	312	7.2	34	2,235	1.52	92.7%
Bindl and Mörmann[35]	2004b	18	3.7	1	67	1.49	92.8%
Bindl and Mörmann[55]	2002	43	3.2	3	142	2.11	90.0%
McLaren and White[56]	2000	223	3.6	9	811	1.11	94.6%
Scotti et al[57]	1995	63	3.1	1	195	0.51	97.5%
Hüls[58]	1995	335	3.0	3	1,005	0.30	98.5%
Total		1,146	4.4	60	5,091		
Summary estimate (95% CI)						1.18 (0.78–1.80)	94.3% (91.4%–96.2%)
Densely sintered alumina							
Vanoorbeek et al[59]	2010	141	2.7	3	377	0.80	96.1%
Kokubo et al[60]	2009	101	4.4	9	441	2.04	90.3%
Walter el al[61]	2005	107	5.6	6	597	1.01	95.1%
Ödman and Andersson[62]	2001	87	7.6	5	662	0.76	96.3%
Oden et al[63]	1998	100	5.0	6	487	1.23	94.0%
Total		536	4.8	29	2,564		
Summary estimate (95% CI)						1.13 (0.78–1.65)	94.5% (92.1%–96.2%)

Table 1 Annual Failure Rates and Survival of Metal-Ceramic and All-Ceramic SCs

Study	Year of publication	Total no. of SCs	Calculated mean exposure time (years)	No. of failures	Total SC exposure time, years	Estimated annual failure rate* (per 100 SCs)	Estimated survival after 5 years*
Densely sintered zirconia, veneered							
Prause et al[64]	2022	36	8.1	2	292	0.68	96.6%
Torres et al[65]	2021	60	3.2	2	189	1.06	94.8%
Serra-Pastor et al[66]	2021	74	5.8	2	429	0.47	97.7%
Seidel et al[51]	2020b	15	2.9	0	44	0	100%
Cagidiaco et al[67]	2019	50	5.0	1	249	0.40	98.0%
Cantner et al[68]	2019	106	3.5	0	371	0	100%
Lundgren et al[52]	2018b	119	5.5	0	655	0	100%
Dogan et al[69]	2017	20	4.9	1	98	1.02	95.0%
Monaco et al[20]	2017b	45	4.9	1	222	0.45	97.8%
Güncü et al[70]	2016	24	3.9	1	94	1.06	94.8%
Ferrari et al[71]	2015	90	3.6	2	328	0.61	97.0%
Rinke et al[25]	2013b	55	3.0	2	158	1.27	93.9%
Sagirkaya et al[72]	2012	74	3.9	4	286	1.40	93.2%
Vigolo and Mutinelli[27]	2012b	20	4.4	2	89	2.25	89.4%
Vigolo and Mutinelli[27]	2012c	20	4.8	1	96	1.04	94.9%
Beuer et al[73]	2010	50	2.9	0	146	0	100%
Schmitt et al[74]	2010	19	3.3	0	62	0	100%
Total		877	4.3	21	3,808		
Summary estimate (95% CI)						0.55 (0.33–0.93)	97.3% (95.5%–98.4%)
Densely sintered zirconia, monolithic or microveneered							
Gseibat et al[75]	2023	30	3.0	0	90	0	100%
Barile et al[76]	2023	34	5.0	1	169	0.59	97.1%
Waldecker et al[77]	2022a	90	6.3	9	567	1.59	92.4%
Waldecker et al[77]	2022b	72	5.2	2	374	0.53	97.4%
Le et al[48]	2022b	30	3.2	0	95	0	100%
Le et al[48]	2022c	30	3.1	1	94	1.06	94.8%
Hammoudi et al[47]	2022b	351	2.2	1	787	0.13	99.4%
Kasem et al[49]	2022b	20	3.0	0	60	0	100%
Gardell et al[50]	2021b	30	3.3	2	100	2.00	90.5%
Solá-Ruíz et al[78]	2021	50	5.0	1	248	0.40	98.0%
Total		737	3.5	17	2,584		
Summary estimate (95% CI)						0.66 (0.28–1.54)	96.8% (92.6%–98.6%)
Overall results		**11,437**	**6.4**	**632**	**72,989**		
Summary estimate (95% CI)						0.87 (0.54–1.39)	95.8% (93.3%–97.3%)

In contrast, metal-ceramic SCs, veneered densely sintered zirconia SCs, and microveneered or monolithic densely sintered zirconia SCs demonstrated survival rates that were not significantly different from those of the monolithic lithium disilicate–reinforced glass-ceramic SCs (Table 2).

Survival in Anterior vs Posterior Regions

No statistically significant differences in survival rates were observed between anterior and posterior single SCs for veneered leucite/lithium disilicate–reinforced glass-ceramic SCs, glass-infiltrated alumina SCs, densely sintered alumina SCs, and veneered densely sintered

Table 2 Summary of Annual Failure Rates, Relative Failure Rates, and Survival Estimates for SCs with Monolithic Lithium Disilicate–Reinforced Glass-Ceramic SCs as Reference

Type of SC	Total no. of SCs	Total exposure time, years	Mean follow-up time, years	Estimated annual failure rate* (95% CI)	5-year survival summary estimate* (95% CI)	Relative failure rate**	*P***
Reinforced glass-ceramic, monolithic	1,106	5,111	4.6	0.29 (0.13–0.66)	98.5% (96.8%–99.3%)	1.00 (Ref.)	
Metal-ceramic	3,509	33,738	9.6	0.59 (0.43–0.80)	97.1% (96.1%–97.9%)	2.00 (0.87–4.60)	.103
Feldspathic/silica-based ceramic	1,501	10,167	6.8	2.02 (1.67–2.44)	90.4% (88.5%–92.0%)	6.87 (3.11–15.20)	< .0001
Reinforced glass-ceramic, veneered	2,025	9,926	4.9	0.88 (0.51–1.51)	95.7% (92.7%–97.5%)	2.99 (1.18–7.59)	.021
Glass-infiltrated alumina	1,146	5,091	4.4	1.18 (0.78–1.80)	94.3% (91.4%–96.2%)	4.02 (1.68–9.57)	.019
Densely sintered alumina	536	2,564	4.8	1.13 (0.78–1.65)	94.5% (92.1%–96.2%)	3.85 (1.65–8.97)	.002
Densely sintered zirconia, veneered	877	3,808	4.3	0.55 (0.33–0.93)	97.3% (95.5%–98.4%)	1.88 (0.74–4.75)	.183
Densely sintered zirconia, monolithic	737	2,584	3.5	0.66 (0.28–1.54)	96.8% (92.6%–98.6%)	2.24 (0.73–6.87)	.158

*Based on robust Poisson regression.
**Based on multivariable robust Poisson regression including all types of SCs.

zirconia SCs. However, feldspathic/silica-based ceramic SCs demonstrated significantly lower survival rates in the posterior region compared to the anterior (95.5% vs 89.4%, *P* < .0001), while metal-ceramic SCs showed significantly lower survival rates in the anterior region compared to the posterior (80.7% vs 94.5%, *P* = .008; Appendix Table 4).

Due to the lack of studies using monolithic lithium disilicate–reinforced glass-ceramic SCs and monolithic densely sintered zirconia SCs in the anterior area, a direct comparison could not be conducted (see Appendix Table 4).

Technical and Biologic Complications

Table 3 and Appendix Table 5 provide an overview of the incidence rates, estimated annual complication and failure rates, and cumulative complication and failure rates of technical and biologic complications across metal-ceramic and all-ceramic SCs.

Over a mean follow-up period of 5 years, 1,528 SCs were analyzed, with an overall failure or complication rate of 11.4%, indicating that 88.6% of the included SCs remained free from all complications. The 5-year failure rates varied by crown material, ranging from 5.3% to 16.0%, with the lowest incidence reported for monolithic densely sintered zirconia SCs and the highest for metal-ceramic SCs. However, due to limited data availability, this analysis could not be performed for feldspathic/silica-based ceramic SCs, glass-infiltrated alumina SCs, densely sintered alumina SCs, or zirconia-silicate SCs.

Technical complications

Core fractures, ceramic fractures, ceramic chippings, loss of retention, marginal discoloration and poor esthetics were technical problems reported for SCs. Core fractures represent a fracture extending through the crown core meaning that the crown has failed. This type of fracture is very rare for metal-ceramic SCs with an estimated 5-year core fracture rate of 0.08%. In general, this problem occurred significantly more often for veneered ceramic SCs (see Table 3 and Appendix Table 5). The incidence of framework fracture was associated with the mechanical stability of the ceramic material. Weaker ceramic SCs such as feldspathic/silica-based ceramic SCs exhibited a 5-year core fracture rate of 6.1%, followed by a fracture rate of 3.4% for densely sintered alumina SCs, 3.2% for glass-infiltrated alumina crowns, 2.1% for veneered leucite/lithium disilicate–reinforced glass-ceramic SCs, and 0.8% for veneered densely sintered zirconia SCs. The monolithic SCs exhibited this problem significantly less frequently, with a 5-year fracture rate of 0.7% for monolithic lithium disilicate–reinforced glass-ceramic SCs and 0% for monolithic densely sintered zirconia, based on 737 included SCs (see Table 3 and Appendix Table 5).

Ceramic fracture or chipping was a common problem. In the present systematic review this data was divided into four categories. The total numbers of ceramic fractures or chippings includes all fractures of the ceramic material from small surface chippings to major fractures of the veneering or core ceramic causing a crown failure.

The second category includes catastrophic fracture of the veneering ceramic so extensive that the crown is a failure. The third category represents a surface chipping that can the repaired with a composite filling or a ceramic veneer adhesively bonded to the existing crown, and the last category includes small surface chipping that can simply be polished (see Table 3 and Appendix Table 5). The overall incidence of ceramic fractures or chippings over an observation period of 5-years was 5.3% based on reports on 4,260 crowns. The highest 5-year incidence 27.5% of ceramic chippings or fractures was reported for zirconia-silicate SCs, follow by glass-infiltrated alumina SCs with a fracture rate of 9.0%, veneered densely sintered zirconia SCs with a fracture rate of 7.9%, veneered leucite/lithium disilicate–reinforced glass-ceramic SCs with a fracture rate of 5.7%, and metal-ceramic SCs with a fracture rate of 5.5%. Lower overall ceramic fracture rates, 1.7% and 0.4%, were reported for monolithic lithium disilicate–reinforced glass-ceramic SCs and monolithic densely sintered zirconia SCs, respectively (see Table 3). The 5-year incidence of crown failure due to a catastrophic fracture of the veneering or the surface ceramic ranged from 0% to 2.5%, with the highest incidence reported for feldspathic/silica based ceramic SCs. This crown failure was a rare failure (0.4%) for monolithic lithium disilicate–reinforced glass-ceramic SCs and did not occur in the 737 monolithic densely sintered zirconia SCs included (see Table 3). The overall incidence of ceramic fractures that needed a repair with composite or additional ceramic veneers was 0.6% over a period of 5 years. This complication was most frequently encountered 1.8% for metal-ceramic SCs. The overall estimated 5-years rate of small ceramic chippings that could be polished was 2.8%, ranging from 0.3% to 5.0%. For traditionally veneered crowns the chipping rate ranged from 2.3% to 5.0% with the highest complication rate reported for glass-infiltrated alumina and veneered densely sintered zirconia SCs (see Table 3). However, significantly (see Appendix Table 5) lower rates of surface ceramic chippings, 0.3% and 0.4%, were reported for monolithic lithium disilicate–reinforced glass-ceramic SCs and monolithic densely sintered zirconia SCs, respectively (see Table 3).

It was not frequent that crowns were remade due to unacceptable esthetic appearance. This outcome was only reported for crowns made of metal-ceramic 0.5%, glass-infiltrated alumina 0.8%, and densely sintered alumina 0.6%. None of the included crowns made of other ceramic material had to be remade due to esthetic issues (see Table 3). Some information on marginal discoloration was available for all the different types of crowns. The incidence ranged from 0% to 57.3%, with the highest rates reported for monolithic densely sintered zirconia SCs (57.3%), glass-infiltrated alumina SCs (18.1%), and monolithic lithium disilicate–reinforced glass-ceramic SCs (15.1%). For other types of crowns, the 5-year incidence of marginal discoloration ranged from 0% to 3.3%. It must, however, be kept in mind that the high discoloration complication rate reported for monolithic densely sintered zirconia crowns was based on one study including 30 crowns (see Table 3).

Biologic complications

Secondary caries on the abutment level and crowns lost due to secondary caries, endodontic failures, or abutment tooth fractures were the most frequently reported biologic complications for SCs. The overall incidence of secondary caries at crown margins was 1.1% over an observation period of 5 years. This result was based on reports on 6,738 crowns. Except for zirconia silicate SCs with a 5-year rate of secondary caries of 7.9% and glass-infiltrated alumina SCs with a rate of 3.4%, the incidence of secondary caries was similar within the other types of crowns ranging between 0.4% and 1.3% (see Table 3). The overall incidence of SCs lost due to secondary caries was 0.3%. This result was based on reports of 8,496 crowns (see Table 3). The failure rate ranged between 0% and 0.6%, and there was no significant difference between different types of crowns (see Table 3 and Appendix Table 5). The 5-year rate of crowns lost due to endodontic failures was 0.6% ranging from 0% to 1.5%, with the highest failure rate reported for metal-ceramic SCs (see Table 3). There was also no significant difference regarding number of crowns lost due to abutment tooth fracture between different types of crowns (see Table 3 and Appendix Table 5), the 5-year failure rate ranged between 0.3% and 1.0% (see Table 3 and Appendix Table 5).

Veneered vs Monolithic Crowns

The annual complication and failure rates of veneered leucite or lithium disilicate–reinforced glass-ceramic SCs were compared to those of monolithic lithium disilicate–reinforced glass-ceramic SCs (Appendix Table 6). The overall estimated annual failure rates of veneered leucite/lithium disilicate–reinforced glass-ceramic SCs (0.88%) was significantly higher (P = .021) compared to monolithic lithium disilicate SCs (0.29%). Furthermore, the incidence of ceramic fractures and chippings, was significantly higher (P = .021) for veneered leucite/lithium disilicate–reinforced glass-ceramic SCs compared to monolithic lithium disilicate–reinforced glass-ceramic SCs. This rate applied for all kinds of ceramic fractures and chippings. On the other hand, the incidence of marginal discoloration was higher for the monolithic crowns (see Appendix Table 6). Subsequently, the annual complication and failure rates of veneered densely sintered zirconia SCs were compared to those of monolithic densely sintered zirconia SCs (Appendix Table 7). The estimated annual failure rate 0.55% of veneered SCs was lower than the respective failure rate 0.66%

Table 3 Overview of Biologic and Technical Complications of Different Types of SCs

Failure/complication	No. of abutments or SCs	Estimated annual complication rates (95% CI)	Cumulative 5-year complication rates (95% CI)	No. of abutments or SCs	Estimated annual complication rates (95% CI)	Cumulative 5-year complication rates (95% CI)
	Overall results—all SCs			Metal-ceramic		
Total number of SCs experiencing biologic complications	4,839	0.55* (0.32–0.96)	2.7%* (1.6%–4.7%)	2,638	0.42* (0.31–0.57)	2.1%* (1.5%–2.8%)
Caries on abutments	6,738	0.23* (0.10–0.55)	1.1%* (0.5%–2.7%)	2,926	0.23* (0.06–0.88)	1.2%* (0.3%–4.3%)
SCs lost due to caries	8,496	0.06* (0.04–0.08)	0.3%* (0.2%–0.4%)	3,218	0.06* (0.04–0.09)	0.3%* (0.2%–0.4%)
SCs lost due to endodontic failures	4,764	0.12* (0.06–0.21)	0.6%* (0.3%–1.1%)	702	0.29* (0.19–0.46)	1.5%* (0.9%–2.3%)
SCs lost due to abutment tooth fracture	8,127	0.16* (0.12–0.21)	0.8%* (0.6%–1.0%)	3,218	0.20* (0.15–0.26)	1.0%* (0.8%–1.3%)
Total number of SCs experiencing technical complications	4,795	0.31* (0.08–1.27)	1.5%* (0.4%–6.1%)	2,616	0.08* (0.01–0.45)	0.4%* (0.07%–2.2%)
Total number of ceramic chippings or fractures	4,260	1.09* (0.73–1.62)	5.3%* (3.6%–7.8%)	633	1.14* (0.50–2.62)	5.5%* (2.5%–12.3%)
Failure due to core fracture	8,469	0.19* (0.06–0.57)	0.9%* (0.3%–2.8%)	3,176	0.02* (0.001–0.17)	0.08%* (0.007%–0.9%)
Minor ceramic chippings - polished	3,486	0.57* (0.37–0.88)	2.8%* (1.8%–4.3%)	500	0.68* (0.15–3.18)	3.4%* (0.7%–14.7%)
Major ceramic chippings – repaired	3,560	0.12* (0.07–0.24)	0.6%* (0.3%–1.2%)	540	0.36* (0.20–0.66)	1.8%* (1.0%–3.2%)
Failure due to catastrophic veneering ceramic fracture	8,250	0.12* (0.05–0.31)	0.6%* (0.2%–1.5%)	3,326	0.05* (0.01–0.18)	0.2%* (0.06%–0.88%)
Loss of retention	7,440	0.13* (0.04–0.37)	0.6%* (0.2%–1.8%)	2,966	0.04* (0.01–0.14)	0.2%* (0.05%–0.7%)
SCs remade due to esthetic issues	6,198	0.07* (0.04–0.12)	0.4%* (0.2%–0.6%)	2,981	0.10* (0.05–0.17)	0.5%* (0.3%–0.8%)
Marginal discoloration	2,128	1.53* (0.78–3.00)	7.4%* (3.8%–13.9%)	306	0.11* (0.03–0.45)	0.5%* (0.1%–2.2%)
Failure/complication	**No. of abutments or SCs**	**Estimated annual complication rates (95% CI)**	**Cumulative 5-year complication rates (95% CI)**	**No. of abutments or SCs**	**Estimated annual complication rates (95% CI)**	**Cumulative 5-year complication rates (95% CI)**
	Glass infiltrated alumina			Densely sintered alumina		
Total number of SCs experiencing biologic complications	149	2.84* (1.72–4.41)	13.3%* (8.2%–19.8%)	0	n.a.	n.a.
Caries on abutments	301	0.69* (0.22–2.12)	3.4%* (1.1%–10.1%)	329	0.27* (0.05–1.37)	1.3%* (0.3%–6.6%)
SCs lost due to caries	834	0.04* (0.01–0.17)	0.2%* (0.04%–0.8%)	536	0.08* (0.03–0.24)	0.4%* (0.1%–1.2%)
SCs lost due to endodontic failures	152	0	0%	242	0	0%
SCs lost due to abutment tooth fracture	834	0.11* (0.04–0.27)	0.5%* (0.2%–1.3%)	536	0.08* (0.01–0.60)	0.4%* (0.05%–2.9%)
Total number of SCs experiencing technical complications	149	3.59* (2.32–5.30)	16.4%* (10.9%–23.3%)	0	n.a.	n.a.
Total number of ceramic chippings or fractures	319	1.90* (0.70–5.14)	9.0%* (3.4%–22.7%)	436	0.53* (0.33–0.85)	2.6%* (1.6%–4.2%)
Failure due to core fracture	983	0.65* (0.31–1.35)	3.2%* (1.6%–6.5%)	536	0.70* (0.60–0.82)	3.4%* (3.0%–4.0%)
Minor ceramic chippings - polished	319	1.02* (0.46–2.26)	5.0%* (2.3%–10.7%)	329	0.47* (0.22–1.00)	2.3%* (1.1%–4.9%)
Major ceramic chippings – repaired	319	0.22* (0.05–0.91)	1.1%* (0.3%–4.4%)	329	0.14* (0.02–1.09)	0.7%* (0.08%–5.3%)
Failure due to catastrophic veneering ceramic fracture	877	0.31* (0.07–1.38)	1.6%* (0.4%–6.7%)	449	0.32* (0.18–0.54)	1.6%* (0.9%–2.7%)
Loss of retention	679	0.20* (0.07–0.56)	1.0%* (0.4%–2.8%)	329	0.74* (0.15–3.78)	3.6%* (0.7%–17.2%)
SCs remade due to esthetic issues	152	0.16* (0.05–0.45)	0.8%* (0.3%–2.2%)	242	0.12* (0.02–0.74)	0.6%* (0.1%–3.7%)
Marginal discoloration	301	3.99* (1.35–11.74)	18.1%* (6.5%–44.4%)	242	0	0%

n.a. = not available.
*Based on robust Poisson regression.

No. of abutments or SCs	Estimated annual complication rates (95% CI)	Cumulative 5-year complication rates (95% CI)	No. of abutments or SCs	Estimated annual complication rates (95% CI)	Cumulative 5-year complication rates (95% CI)	No. of abutments or SCs	Estimated annual complication rates (95% CI)	Cumulative 5-year complication rates (95% CI)
Feldspathic/silica-ceramic			Reinforced glass-ceramic—veneered			Reinforced glass-ceramic—monolithic		
0	n.a.	n.a.	412	1.27* (0.52–3.16)	6.2%* (2.6%–14.6%)	650	0.71* (0.30–1.68)	3.5%* (1.5%–8.0%)
422	0	0%	559	0.08* (0.02–0.27)	0.4%* (0.1%–1.3%)	819	0.17* (0.05–0.57)	0.9%* (0.3%–2.8%)
440	0	0%	1,071	0.06* (0.01–0.29)	0.3%* (0.07%–1.4%)	819	0.10* (0.03–0.40)	0.5%* (0.1%–2.0%)
321	0	0%	827	0.10* (0.02–0.49)	0.5%* (0.1%–2.4%)	819	0.03* (0.005–0.25)	0.2%* (0.02%–1.2%)
381	0.19* (0.03–1.25)	0.9%* (0.1%–6.1%)	929	0.07* (0.02–0.33)	0.4%* (0.08%–1.6%)	711	0.09* (0.01–0.62)	0.4%* (0.06%–3.1%)
0	n.a.	n.a.	438	1.37* (0.77–2.43)	6.6%* (3.8%–11.5%)	696	0.67* (0.28–1.58)	3.3%* (1.4%–7.6%)
127	0.72* (0.22–2.29)	3.5%* (1.1%–10.8%)	638	1.18* (0.74–1.88)	5.7%* (3.6%–9.0%)	711	0.35* (0.13–0.91)	1.7%* (0.7%–4.5%)
440	1.25* (0.36–4.36)	6.1%* (1.8%–19.6%)	1,071	0.42* (0.14–1.30)	2.1%* (0.7%–6.3%)	685	0.14* (0.04–0.46)	0.7%* (0.2%–2.2%)
127	0.48* (0.09–2.55)	2.4%* (0.4%–12.0%)	436	0.77* (0.51–1.16)	3.8%* (2.5%–5.7%)	538	0.05* (0.02–0.16)	0.3%* (0.09%–0.8%)
127	0	0%	436	0	0%	538	0.05* (0.007–0.39)	0.3%* (0.04%–1.9%)
440	0.51* (0.28–0.93)	2.5%* (1.4%–4.5%)	929	0.24* (0.10–0.55)	1.2%* (0.5%–2.7%)	711	0.09* (0.02–0.41)	0.4%* (0.09%–2.0%)
321	0.08* (0.005–1.16)	0.4%* (0.03%–5.6%)	777	0.16* (0.03–0.87)	0.8%* (0.2%–4.3%)	1,091	0.13* (0.04–0.53)	0.7%* (0.2%–2.6%)
321	0	0%	721	0	0%	755	0	0%
210	0.68* (0.17–2.74)	3.3%* (0.8%–12.8%)	357	0.67* (0.21–2.15)	3.3%* (1.0%–10.2%)	234	3.27* (0.86–12.45)	15.1%* (4.2%–46.3%)

No. of abutments or SCs	Estimated annual complication rates (95% CI)	Cumulative 5-year complication rates (95% CI)	No. of abutments or SCs	Estimated annual complication rates (95% CI)	Cumulative 5-year complication rates (95% CI)	No. of abutments or SCs	Estimated annual complication rates (95% CI)	Cumulative 5-year complication rates (95% CI)
Densely sintered zirconia—veneered			Densely sintered zirconia—monolithic			Zirconia silicate		
273	0.25* (0.09–0.72)	1.3%* (0.5%–3.6%)	717	0.87* (0.30–2.48)	4.3%* (1.5%–11.7%)	0	n.a.	n.a.
572	0.08* (0.02–0.31)	0.4%* (0.09%–1.5%)	687	0.21* (0.05–0.89)	1.1%* (0.3%–4.4%)	123	1.66* (0.72–3.24)	7.9%* (3.5%–14.9%)
841	0	0%	737	0.12* (0.03–0.43)	0.6%* (0.2%–2.12%)	0	n.a.	n.a.
841	0.06* (0.01–0.23)	0.3%* (0.07%–1.1%)	737	0.15* (0.06–0.43)	0.8%* (0.3%–2.1%)	123	0.20* (0.005–1.15)	1.0%* (0.1%–5.6%)
781	0.06* (0.02–0.23)	0.3%* (0.08%–1.2%)	737	0.15* (0.07–0.33)	0.8%* (0.4%–1.6%)	0	n.a.	n.a.
193	0.90* (0.44–1.85)	4.4%* (2.2%–8.8%)	703	0.74* (0.35–1.58)	3.7%* (1.7%–7.6%)	0	n.a.	n.a.
570	1.64* (0.92–2.92)	7.9%* (4.5%–13.6%)	703	0.08* (0.03–0.22)	0.4%* (0.2%–1.1%)	123	6.41* (4.40–8.99)	27.5%* (19.8%–36.2%)
841	0.17* (0.07–0.42)	0.8%* (0.3%–2.1%)	737	0	0%	0	n.a.	n.a.
534	1.02* (0.45–2.32)	5.0%* (2.2%–10.9%)	703	0.08* (0.03–0.22)	0.4%* (0.2%–1.1%)	0	n.a.	n.a.
534	0.20* (0.05–0.91)	1.0%* (0.2%–4.4%)	737	0	0%	0	n.a.	n.a.
781	0.24* (0.11–0.52)	1.2%* (0.6%–2.6%)	737	0	0%	0	n.a.	n.a.
540	0.17* (0.05–0.62)	0.8%* (0.2%–3.1%)	737	0.62* (0.26–1.45)	3.0%* (1.3%–7.0%)	0	n.a.	n.a.
561	0	0%	465	0	0%	0	n.a.	n.a.
448	0.47* (0.11–1.99)	2.3%* (0.5%–9.4%)	30	17.0* (10.22–25.82)	57.3%* (40.0%–72.5%)	0	n.a.	n.a.

reported for the monolithic SCs. This difference, however, did not reach statistical difference (*P* = .721). The incidence of ceramic fractures and chippings was also significantly higher for veneered densely sintered zirconia SCs compared to monolithic densely sintered SCs, similar to the reinforced glass-ceramic SCs (see Appendix Table 7). Hence, by avoiding traditional veneering of ceramic crowns the incidence of ceramic fractures and chipping was reduced.

Quality Assessment of the Included Studies

Appendix Table 8 reports the quality assessment of the included studies. Among the patient cohorts, 31 were rated as high quality, 52 as moderate quality, and only 1 as low quality.

DISCUSSION

The findings of the present systematic review and meta-analysis indicate that reinforced glass-ceramic (both veneered and monolithic) and densely sintered zirconia (both veneered and monolithic) exhibit similar estimated annual failure rates and 5-year survival rates as metal-ceramic SCs, which were traditionally regarded as the gold standard. Furthermore, among all evaluated material/design combinations, monolithic lithium disilicate glass-ceramic performed the best and should be considered as the current gold standard for the testing of new ceramics or hybrid materials for fixed restorations.

The present review also showed that weaker ceramics like feldspathic/silica-based ceramic SCs, densely sintered alumina SCs, and glass-infiltrated alumina SCs showed significantly higher failure rates compared to metal-ceramic SCs. When monolithic lithium disilicate SCs—identified as the best-performing reconstructive material in the present review—were used as the reference instead of metal-ceramic SCs, veneered lithium disilicate–reinforced SCs had also to be grouped with feldspathic/silica-based ceramic, glass-infiltrated alumina, and densely sintered alumina SCs, all of which demonstrated significantly higher failure rates. These outcomes indicate that veneering of core materials in the traditional way (ie, applying the veneering ceramic in the shape of the desired tooth on a small core bearing all the occlusion and function) increases the risk for technical complications such as chipping or fracture of the veneering ceramic. This problem was reported before, hence, if purely monolithic use of the restorative material is not feasible for esthetic reasons, microveneering and new designs for the veneering of the more recent generations of restorations should be considered,[80] like a window veneering.

In the present review, all-ceramic SCs consistently demonstrated fewer esthetic failures than metal-ceramic SCs, which significantly failed in anterior regions. Problems with the esthetics of metal-ceramics may be a predominant reason for the removal.

Regarding biologic outcomes, in general the all-ceramic crowns exhibited very good outcomes, exceeding the ones of the metal-ceramics. The feldspathic/silica-based ceramics showed the lowest incidence of secondary caries and endodontic complications, and monolithic lithium disilicate glass-ceramic, glass-infiltrated alumina, densely sintered alumina, and veneered densely sintered zirconia SCs were associated with significantly fewer endodontic failures compared to metal-ceramic SCs.

Overall, all-ceramic SCs were associated with a significantly higher incidence of technical complications compared to metal-ceramic SCs. Weaker ceramics, such as feldspathic/silica-based ceramics, glass-infiltrated alumina, and densely sintered alumina, demonstrated consistently higher rates of core and catastrophic fractures relative to metal-ceramic SCs.

Across all material groups, the most frequently observed technical complication was surface chipping or fracture. This technical problem was reported in numerous other systematic reviews on veneered restorations on teeth and implants[81–83] and, as mentioned previously, remains to be the weak link of the traditional types of veneered restorations, frequently associated with the strength of the veneering ceramic itself and the connection of the veneering ceramic and the underlying core.[84] With respect to surface chipping, monolithic restorations fabricated from densely sintered zirconia or lithium disilicate–reinforced glass ceramic exhibited the lowest rates for both major and minor chipping, significantly outperforming veneered restorations. This observation was made before for restorations supported by implants.[2,85]

Unlike the previous systematic review published in 2015,[5] the present analysis distinguished outcomes according to monolithic and veneered designs for both lithium disilicate–reinforced glass-ceramic and densely sintered zirconia SCs. The restriction to the inclusion of solely prospective studies strengthens the validity of the findings by minimizing missing data and enhancing completeness of outcome reporting. Nevertheless, this approach may lead to an underestimation of biologic complications, because patients enrolled in prospective studies typically receive continuous clinical follow-up and professional hygiene maintenance treatments throughout the observation period, potentially reducing the incidence of biologic failures. Furthermore, the exclusion of retrospective studies may have limited the statistical power of certain subgroup analyses.

The findings of this systematic review confirm that all-ceramic SCs are durable and favorable alternatives to metal-ceramic SCs, offering several advantages such as improved esthetic outcomes and the potential for more conservative tooth preparation.[86,87] In particular, monolithic lithium disilicate–reinforced glass-ceramic and densely sintered zirconia SCs demonstrated the most favorable technical outcomes. However, one of the main limitations of monolithic crowns is their reduced esthetic performance in anterior regions, where veneering may still be necessary. To address this limitation, a veneering approach, often referred to in literature as partial- or microveneering, may be applied in exclusively to non-functional areas, thereby enhancing esthetics while minimizing the risk of surface chipping and failure associated with catastrophic veneering ceramic fractures.[88,89] Unfortunately, only three studies included in this review have exclusively evaluated microveneered crowns,[47,48,77] providing preliminary results comparable to those of fully monolithic restorations and warrant further investigation in future research. Moreover, monolithic SCs, both zirconia-based and lithium disilicate, exhibited significantly more marginal discoloration compared to other crown types. This result could be associated with the accuracy of the respective fabrication procedures influencing the sealing of the cementation gap.

Finally, no new studies since 2014 were identified for glass-infiltrated and densely sintered alumina, suggesting that these materials may be now considered obsolete and have been largely replaced by densely sintered zirconia and lithium disilicate for SCs, due to their superior mechanical properties and lower cost.[90]

Our research group has previously published two systematic reviews with meta-analyses assessing the survival and complication rates of metal-ceramic and all-ceramic tooth-supported SCs. The first review, published in 2007,[1] included 6 studies on metal-ceramic SCs and 28 studies on all-ceramic SCs, of which 62% were prospective and 38% retrospective. The second review, published in 2015,[5] identified 17 studies on metal-ceramic SCs and 50 studies on all-ceramic SCs, with a similar distribution of study design (63% prospective, 37% retrospective).

In preparing the present systematic review, only prospective studies were included, while retrospective studies were excluded in recognition of the higher level of evidence provided by prospective designs. Furthermore, reinforced glass-ceramic and densely sintered zirconia crowns were stratified according to design, differentiating between veneered and monolithic cohorts. For most material/design categories, this subdivision did not significantly affect the primary outcomes.

The estimated 5-year survival rates showed remarkable consistency for metal-ceramic SCs across the three reviews: 95.6% in 2007, 95.7% in 2015, and 97.1% in the present review. Comparable trends were observed for glass-ceramic SCs (87.5%, 90.7%, and 90.4%), glass-infiltrated alumina SCs (96.4%, 95.6%, and 94.3%), and densely sintered alumina SCs (96.4%, 96.0%, and 94.5%). The most notable improvement was found for zirconia-ceramic SCs. While no eligible studies were available in 2007, the 2015 review reported a 5-year survival rate of 93.8%, which has since increased to 97.3% for veneered and 96.8% for monolithic zirconia-ceramic crowns. This improvement corresponds to a reduction in the annual failure rate from 1.28% to 0.55% for veneered and 0.66% for monolithic, representing a decrease of more than 50%. These improvements are likely attributable to increased awareness of design requirements for veneered zirconia restorations and advancements in veneering ceramics.

The present review included 19 RCTs, of which 10 addressed material/design aspects of restorations. None of the included RCTs demonstrated statistically significant differences in survival between material/design groups. This result may indicate either the absence of clinically relevant differences or insufficient statistical power, because many studies evaluated relatively small patient groups (15 to 50 restorations per group). Two RCTs directly compared reinforced glass-ceramic SCs to zirconia-ceramic SCs, with larger sample sizes (≈ 110 and ≈ 350 restorations per group).[47,52] Both studies, consistent with the present review, reported no significant differences between the two ceramic systems.

One of the limitations of the available evidence is that annual failure rates could not be estimated for specific follow-up intervals. Consequently, it was not possible to determine whether failure rates follow a linear trajectory or vary over time.

Research Implications

It was evident from the search of the dental literature that there is a need for longitudinal studies reporting on tooth-supported SCs with 10 or more years of follow-up. The present systematic review revealed several shortcomings in the conduct and reporting of clinical studies on tooth-supported SCs leading to the following recommendations: Long-term cohort studies on reconstructions should be prospective and have complete follow-up information, preferentially with similar follow-up period for all patients. Owing to various definitions of success, authors should report data on survival/failures in combination with incidence of complications. Survival and success (free of all complications) of the restorations should be reported. Validated criteria should be used for the assessment of the biologic and technical complications. Furthermore, all potential complications should be addressed and reported giving the reader a complete overview of the outcome.

The presently proposed QAS-RS shall account for this in the future and support authors in designing clinical research projects and enhance the reporting.

CONCLUSIONS

All-ceramic SCs supported by teeth are a well-documented and reliable treatment option. The use of metal-ceramics as restorative material and as gold standard for SCs, however, is no longer justified. Monolithic lithium disilicate–reinforced glass ceramic can be considered the new reference material for all-ceramic SCs. The use of monolithic ceramic crowns, in contrast to veneered designs, enhances clinical longevity and stability.

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REFERENCES

1. Pjetursson BE, Sailer I, Zwahlen M, Hämmerle CHF. A systematic review of the survival and complication rates of all-ceramic and metal-ceramic reconstructions after an observation period of at least 3 years. Part I: Single crowns. Clin Oral Implants Res 2007;18(suppl 3):73–85.
2. Pjetursson BE, Valente NA, Strasding M, Zwahlen M, Liu S, Sailer I. A systematic review of the survival and complication rates of zirconia-ceramic and metal-ceramic single crowns. Clin Oral Implants Res 2018;29(suppl 16):199–214.
3. Sailer I, Strasding M, Valente NA, Zwahlen M, Liu S, Pjetursson BE. A systematic review of the survival and complication rates of zirconia-ceramic and metal-ceramic multiple-unit fixed dental prostheses. Clin Oral Implants Res 2018;29(suppl 16):184–198.
4. Pjetursson BE, Sailer I, Makarov NA, Zwahlen M, Thoma DS. All-ceramic or metal-ceramic tooth-supported fixed dental prostheses (FDPs)? A systematic review of the survival and complication rates. Part II: Multiple-unit FDPs. Dent Mater 2015;31:624–639.
5. Sailer I, Makarov NA, Thoma DS, Zwahlen M, Pjetursson BE. All-ceramic or metal-ceramic tooth-supported fixed dental prostheses (FDPs)? A systematic review of the survival and complication rates. Part I: Single crowns (SCs). Dent Mater 2015;31:603–623.
6. Mello CC, Lemos CAA, de Luna Gomes JM, Verri FR, Pellizzer EP. CAD/CAM vs conventional technique for fabrication of implant-supported frameworks: A systematic review and meta-analysis of in vitro studies. Int J Prosthodont 2019;32:182–192.
7. Leitão CIMB, Fernandes GV de O, Azevedo LPP, Araújo FM, Donato H, Correia ARM. Clinical performance of monolithic CAD/CAM tooth-supported zirconia restorations: Systematic review and meta-analysis. J Prosthodont Res 2022;66:374–384.
8. Lin WS, Chen L, Alfaraj A. 3D-printed zirconia and lithium disilicate in dentistry and their clinical applications. Int J Prosthodont 2025;38:12–26.
9. Sailer I, Pjetursson BE, Zwahlen M, Hämmerle CHF. A systematic review of the survival and complication rates of all-ceramic and metal-ceramic reconstructions after an observation period of at least 3 years. Part II: Fixed dental prostheses. Clin Oral Implants Res 2007;18(suppl 3):86–96.
10. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ 2021;372:n71.
11. Wells GA, Shea BJ, O'Connell D, et al. The Newcastle-Ottawa Scale (NOS) for Assessing the Quality of Non-Randomised Studies in Meta-Analyses.
12. Romandini P, Marruganti C, Romandini WG, Sanz M, Grandini S, Romandini M. Are periodontitis and dental caries associated? A systematic review with meta-analyses. J Clin Periodontol 2024;51:145–157.
13. Carra MC, Romandini P, Romandini M. Risk of bias evaluation of cross-sectional studies: Adaptation of the Newcastle-Ottawa Scale [epub ahead of print 28 Apr 2025]. J Periodontal Res doi:10.1111/jre.13405.
14. Kirkwood BR, Sterne JAC. Chapter 24: Poisson regression. In: Essential Medical Statistics, ed 2. Blackwell Science, 2003.
15. Kirkwood BR, Sterne JAC. Chapter 26: Survival analysis: Displaying and comparing survival patterns. In: Essential Medical Statistics, ed 2. Blackwell Science, 2003.
16. Poletto-Neto V, Chisini LA, Fokkinga W, et al. Single crown vs. composite for glass fiber post-retained restorations: An 8-year randomized clinical trial. J Dent 2024;142:104837.
17. Bacher H, Schweyen R, Olms C, Arnold C, Setz J, Hey J. 10-year clinical comparative study of ceramic and composite veneered metal crowns. Eur J Prosthodont Restor Dent 2021;29(3).
18. Chaar MS, Passia N, Kern M. Long-term clinical outcome of posterior metal-ceramic crowns fabricated with direct metal laser-sintering technology. J Prosthodont Res 2020;64:354–357.
19. Brondani LP, Pereira-Cenci T, Wandsher VF, Pereira GK, Valandro LF, Bergoli CD. Longevity of metal-ceramic crowns cemented with self-adhesive resin cement: A prospective clinical study. Braz Oral Res 2017;31:e22.
20. Monaco C, Llukacej A, Baldissara P, Arena A, Scotti R. Zirconia-based versus metal-based single crowns veneered with overpressing ceramic for restoration of posterior endodontically treated teeth: 5-year results of a randomized controlled clinical study. J Dent 2017;65:56–63.
21. Ohlmann B, Bermejo JL, Rammelsberg P, Schmitter M, Zenthöfer A, Stober T. Comparison of incidence of complications and aesthetic performance for posterior metal-free polymer crowns and metal-ceramic crowns: Results from a randomized clinical trial. J Dent 2014;42:671–676.
22. Hey J, Beuer F, Bensel T, Boeckler AF. Single crowns with CAD/CAM-fabricated copings from titanium: 6-year clinical results. J Prosthet Dent 2014;112:150–154.
23. Tao J, Wu Y, Chen J, Su J. A follow-up study of up to 5 years of metal-ceramic crowns in maxillary central incisors for different gingival biotypes. Int J Periodontics Restorative Dent 2014;34:e85–e92.
24. Reitemeier B, Hänsel K, Kastner C, Weber A, Walter MH. A prospective 10-year study of metal ceramic single crowns and fixed dental prosthesis retainers in private practice settings. J Prosthet Dent 2013;109:149–155.
25. Rinke S, Schäfer S, Lange K, Gersdorff N, Roediger M. Practice-based clinical evaluation of metal-ceramic and zirconia molar crowns: 3-year results. J Oral Rehabil 2013;40:228–237.
26. Walton TR. The up to 25-year survival and clinical performance of 2,340 high gold-based metal-ceramic single crowns. Int J Prosthodont 2013;26:151–160.
27. Vigolo P, Mutinelli S. Evaluation of zirconium-oxide-based ceramic single-unit posterior fixed dental prostheses (FDPs) generated with two CAD/CAM systems compared to porcelain-fused-to-metal single-unit posterior FDPs: A 5-year clinical prospective study. J Prosthodont 2012;21:265–269.
28. Naumann M, Ernst J, Reich S, Weißhaupt P, Beuer F. Galvano- vs. metal-ceramic crowns: Up to 5-year results of a randomised split-mouth study. Clin Oral Investig 2011;15:657–660.
29. Güngör MA, Artunç C, Dündar M. Seven-year clinical follow-up study of Probond ceramic crowns. Quintessence Int 2007;38:e456–e463.A
30. Marklund S, Bergman B, Hedlund SO, Nilson H. An intraindividual clinical comparison of two metal-ceramic systems: A 5-year prospective study. Int J Prosthodont 2003;16:70–73.
31. Fages M, Raynal J, Tramini P, Cuisinier FJ, Durand JC. Chairside computer-aided design/computer-aided manufacture all-ceramic crown and endocrown restorations: A 7-year survival rate study. Int J Prosthodont 2017;30:556–560.
32. Cehreli MC, Kokat AM, Ozpay C, Karasoy D, Akca K. A randomized controlled clinical trial of feldspathic versus glass-infiltrated alumina all-ceramic crowns: A 3-year follow-up. Int J Prosthodont 2011;24:77–84.
33. Burke FJT. Four year performance of dentine-bonded all-ceramic crowns. Br Dent J 2007;202:269–273.
34. Malament KA, Socransky SS. Survival of Dicor glass-ceramic dental restorations over 20 years: Part IV. The effects of combinations of variables. Int J Prosthodont 2010;23:134–140.
35. Bindl A, Mörmann WH. Survival rate of mono-ceramic and ceramic-core CAD/CAM-generated anterior crowns over 2-5 years. Eur J Oral Sci 2004;112:197–204.

36. Kelsey WP, Cavel T, Blankenau RJ, Barkmeier WW, Wilwerding TM, Latta MA. 4-year clinical study of castable ceramic crowns. Am J Dent 1995;8:259–262.
37. Špehar D, Jakovac M. Clinical survival of reduced-thickness monolithic lithium-disilicate crowns: A 3-year randomized controlled trial. Acta Stomatol Croat 2024;58:123–135.
38. Margvelashvili-Malament M, Thompson V, Polyakov V, Malament KA. Over 14-year survival of pressed e.max lithium disilicate glass-ceramic complete and partial coverage restorations in patients with severe wear: A prospective clinical study. J Prosthet Dent 2025;133:737–746.
39. Teichmann M, Göckler F, Weber V, Yildirim M, Wolfart S, Edelhoff D. Ten-year survival and complication rates of lithium-disilicate (Empress 2) tooth-supported crowns, implant-supported crowns, and fixed dental prostheses. J Dent 2017;56:65–77.
40. Huettig F, Gehrke UP. Early complications and performance of 327 heat-pressed lithium disilicate crowns up to five years. J Adv Prosthodont 2016;8:194–200.
41. Toman M, Toksavul S. Clinical evaluation of 121 lithium disilicate all-ceramic crowns up to 9 years. Quintessence Int 2015;46:189–197.
42. Gehrt M, Wolfart S, Rafai N, Reich S, Edelhoff D. Clinical results of lithium-disilicate crowns after up to 9 years of service. Clin Oral Investig 2013;17:275–284.
43. Marquardt P, Strub JR. Survival rates of IPS empress 2 all-ceramic crowns and fixed partial dentures: Results of a 5-year prospective clinical study. Quintessence Int 2006;37:253–259.
44. Sorensen JA, Choi C, Fanuscu MI, Mito WT. IPS Empress crown system: Three-year clinical trial results. J Calif Dent Assoc 1998;26:130–136.
45. Studer S, Lehner C, Brodbeck U, Schärer P. Six-year results of leucite-reinforced glass ceramic crowns. Acta Med Dent Helv. Mater Sci 1998:2180–2225.
46. Rauch A, Lorenz L, Reich S, Hahnel S, Schmutzler A, Schierz O. Long-term survival of monolithic tooth-supported lithium disilicate crowns fabricated using a chairside approach: 15-year results. Clin Oral Investig 2023;27:3983–3989.
47. Hammoudi W, Trulsson M, Svensson P, Smedberg JI. Long-term results of a randomized clinical trial of 2 types of ceramic crowns in participants with extensive tooth wear. J Prosthet Dent 2022;127:248–257.
48. Le M, Dirawi W, Papia E, Larsson C. Clinical outcome of three different types of posterior all-ceramic crowns. A 3-year follow-up of a multicenter, randomized, controlled clinical trial. Int J Prosthodont 2023;36:546–553.
49. Kasem AT, Ellayeh M, Özcan M, Sakrana AA. Three-year clinical evaluation of zirconia and zirconia-reinforced lithium silicate crowns with minimally invasive vertical preparation technique. Clin Oral Investig 2023;27:1577–1588.
50. Gardell E, Larsson C, von Steyern PV. Translucent zirconium dioxide and lithium disilicate: A 3-year follow-up of a prospective, practice-based randomized controlled trial on posterior monolithic crowns. Int J Prosthodont 2021;34:163–172.
51. Seidel A, Belli R, Breidebach N, Wichmann M, Matta RE. The occlusal wear of ceramic fixed dental prostheses: 3-year results in a randomized controlled clinical trial with split-mouth design. J Dent 2020;103:103500.
52. Lundgren GP, Vestlund GIM, Dahllöf G. Crown therapy in young individuals with amelogenesis imperfecta: Long term follow-up of a randomized controlled trial. J Dent. 2018;76:102–108.
53. Cortellini D, Canale A. Bonding lithium disilicate ceramic to feather-edge tooth preparations: A minimally invasive treatment concept. J Adhes Dent 2012;14:7–10.
54. Kokubo Y, Tsumita M, Sakurai S, Suzuki Y, Tokiniwa Y, Fukushima S. Five-year clinical evaluation of In-Ceram crowns fabricated using GN-I (CAD/CAM) system. J Oral Rehabil 2011;38:601–607.
55. Bindl A, Mörmann WH. An up to 5-year clinical evaluation of posterior in-ceram CAD/CAM core crowns. Int J Prosthodont 2002;15:451–456.
56. McLaren EA, White SN. Survival of In-Ceram crowns in a private practice: a prospective clinical trial. J Prosthet Dent 2000;83:216–222.
57. Scotti R, Catapano S, D'Elia A. A clinical evaluation of In-Ceram crowns. Int J Prosthodont 1995;8:320–323.
58. Hüls A. Zum Stand der klinischen Bewährung infiltrationskeramischer Verblendkronen. Deutsche Zahnärztliche Zeitschrift 1995;50:674–676.
59. Vanoorbeek S, Vandamme K, Lijnen I, Naert I. Computer-aided designed/computer-assisted manufactured composite resin versus ceramic single-tooth restorations: A 3-year clinical study. Int J Prosthodont 2010;23:223–230.
60. Kokubo Y, Sakurai S, Tsumita M, Ogawa T, Fukushima S. Clinical evaluation of Procera AllCeram crowns in Japanese patients: results after 5 years. J Oral Rehabil 2009;36:786–791.
61. Walter MH, Wolf BH, Wolf AE, Boening KW. Six-year clinical performance of all-ceramic crowns with alumina cores. Int J Prosthodont 2006;19:162–163.
62. Odman P, Andersson B. Procera AllCeram crowns followed for 5 to 10.5 years: a prospective clinical study. Int J Prosthodont 2001;14:504–509.
63. Odén A, Andersson M, Krystek-Ondracek I, Magnusson D. Five-year clinical evaluation of Procera AllCeram crowns. J Prosthet Dent 1998;80:450–456.
64. Prause E, Hey J, Sterzenbach G, Beuer F, Adali U. Survival and success of veneered zirconia crowns. Int J Comput Dent 2023;26:247–255.
65. Torres C, Ávila D, Gonçalves LL, et al. Glass ionomer versus self-adhesive cement and the clinical performance of zirconia coping/press-on porcelain crowns. Oper Dent 2021;46:362–373.
66. Serra-Pastor B, Bustamante-Hernández N, Fons-Font A, Fernanda Solá-Ruíz M, Revilla-León M, Agustín-Panadero R. Periodontal behavior and patient satisfaction of anterior teeth restored with single zirconia crowns using a biologically oriented preparation technique: A 6-year prospective clinical study. J Clin Med 2021;10:3482.
67. Cagidiaco EF, Discepoli N, Goracci C, Carboncini F, Vigolo P, Ferrari M. Randomized clinical trial on single zirconia crowns with feather-edge vs chamfer finish lines: Four-year results. Int J Periodontics Restorative Dent 2019;39:817–826.
68. Cantner F, Cacaci C, Mücke T, Randelzhofer P, Hajtó J, Beuer F. Clinical performance of tooth- or implant-supported veneered zirconia single crowns: 42-month results. Clin Oral Investig 2019;23:4301–4309.
69. Dogan S, Raigrodski AJ, Zhang H, Mancl LA. Prospective cohort clinical study assessing the 5-year survival and success of anterior maxillary zirconia-based crowns with customized zirconia copings. J Prosthet Dent 2017;117:226–232.
70. Güncü MB, Cakan U, Aktas G, Güncü GN, Canay S. Comparison of implant versus tooth-supported zirconia-based single crowns in a split-mouth design: a 4-year clinical follow-up study. Clin Oral Investig 2016;20:2467–2473.
71. Ferrari M, Sorrentino R, Cagidiaco C, et al. Short-term clinical performance of zirconia single crowns with different framework designs: 3-year clinical trial. Am J Dent 2015;28:235–240.
72. Sagirkaya E, Arikan S, Sadik B, Kara C, Karasoy D, Cehreli M. A randomized, prospective, open-ended clinical trial of zirconia fixed partial dentures on teeth and implants: interim results. Int J Prosthodont 2012;25:221–231.
73. Beuer F, Stimmelmayr M, Gernet W, Edelhoff D, Güth JF, Naumann M. Prospective study of zirconia-based restorations: 3-year clinical results. Quintessence Int 2010;41:631–637.
74. Schmitt J, Wichmann M, Holst S, Reich S. Restoring severely compromised anterior teeth with zirconia crowns and feather-edged margin preparations: A 3-year follow-up of a prospective clinical trial. Int J Prosthodont 2010;23:107–109.
75. Gseibat M, Sevilla P, Lopez-Suarez C, Rodriguez V, Pelaez J, Suarez MJ. Performance of posterior third-generation monolithic zirconia crowns in a complete digital workflow: A three-year prospective clinical study. J Dent Sci 2024;19:871–877.
76. Barile G, Capodiferro S, Muci G, et al. Clinical outcomes of monolithic zirconia crowns on posterior natural abutments performed by final year dental medicine students: A prospective study with a 5-year follow-up. Int J Environ Res Public Health 2023;20:2943.
77. Waldecker M, Behnisch R, Rammelsberg P, Bömicke W. Five-year clinical performance of monolithic and partially veneered zirconia single crowns—A prospective observational study. J Prosthodont Res 2022;66:339–345.
78. Solá-Ruiz MF, Baixauli-López M, Roig-Vanaclocha A, Amengual-Lorenzo J, Agustín-Panadero R. Prospective study of monolithic zirconia crowns: Clinical behavior and survival rate at a 5-year follow-up. J Prosthodont Res 2021;65:284–290.
79. Passia N, Stampf S, Strub JR. Five-year results of a prospective randomised controlled clinical trial of posterior computer-aided design-computer-aided manufacturing ZrSiO4 -ceramic crowns. J Oral Rehabil 2013;40:609–617.

80. Strasding M, Hicklin SP, Todorovic A, Fehmer V, Mojon P, Sailer I. A multicenter randomized controlled clinical pilot study of buccally micro-veneered lithium-disilicate and zirconia crowns supported by titanium base abutments: 1-year outcomes. Clin Oral Implants Res 2023;34:56–65.
81. Pjetursson BE, Sailer I, Latyshev A, Rabel K, Kohal RJ, Karasan D. A systematic review and meta-analysis evaluating the survival, the failure, and the complication rates of veneered and monolithic all-ceramic implant-supported single crowns. Clin Oral Implants Res 2021;32(suppl 21):254–288.
82. Pjetursson BE, Sailer I, Merino-Higuera E, Spies BC, Burkhardt F, Karasan D. Systematic review evaluating the influence of the prosthetic material and prosthetic design on the clinical outcomes of implant-supported multi-unit fixed dental prosthesis in the posterior area. Clin Oral Implants Res 2023;34(suppl 26):86–103.
83. Sailer I, Karasan D, Todorovic A, Ligoutsikou M, Pjetursson BE. Prosthetic failures in dental implant therapy. Periodontol 2000 2022;88:130–144.
84. Papia E, Larsson C. Material-related complications in implant-supported fixed dental restorations. A systematic review. Eur J Oral Implantol 2018;11(suppl 1):S147–S165.
85. Pieralli S, Kohal RJ, Rabel K, von Stein-Lausnitz M, Vach K, Spies BC. Clinical outcomes of partial and full-arch all-ceramic implant-supported fixed dental prostheses. A systematic review and meta-analysis. Clin Oral Implants Res 2018;29(suppl 18):224–236.
86. Edelhoff D, Sorensen JA. Tooth structure removal associated with various preparation designs for posterior teeth. Int J Periodontics Restorative Dent 2002;22:241–249.
87. Edelhoff D, Sorensen JA. Tooth structure removal associated with various preparation designs for anterior teeth. J Prosthet Dent 2002;87:503–509.
88. Sailer I, Mühlemann S, Kohal RJ, et al. Reconstructive aspects: Summary and consensus statements of group 3. The 5th EAO Consensus Conference 2018. Clin Oral Implants Res 2018;29(suppl 18):237–242.
89. Jokstad A, Pjetursson BE, Mühlemann S, et al. Fabrication, workflow and delivery of reconstruction: Summary and consensus statements of group 4. The 6th EAO Consensus Conference 2021. Clin Oral Implants Res 2021;32(suppl 21):336–341.
90. Blatz MB, Vonderheide M, Conejo J. The effect of resin bonding on long-term success of high-strength ceramics. J Dent Res 2018;97:132–139.

Highlighted Literature

The Submucosal Microbiome Correlates with Peri-implantitis Severity

Peri-implantitis is an increasingly prevalent chronic inflammatory disease of the peri-implant tissue. A key etiologic factor for peri-implantitis is the submucosal biofilm, which may further drive clinical severity and accelerate disease progression. The present cross-sectional study aimed to characterize the compositional (full-length 16S rRNA gene amplicon sequencing) and functional patterns (metatranscriptomics) in the microbiome as an indicator of peri-implantitis severity. For this purpose, submucosal biofilm samples were collected from 49 peri-implantitis-diagnosed implants in 34 patients. Notable microbial signatures were associated with increased probing depth (PD), a measure for disease severity. Multivariate linear regression analysis, adjusted for patient variability, showed that the genera Capnocytophaga and Gemella were negatively correlated with increased peri-implantitis severity whereas Pseudoramibacter was positively correlated with it. PICRUSt2-based metabolic pathway prediction revealed the following to be negatively correlated with PD: central carbon metabolism, nitrate reduction, sulfate assimilation, glycolysis, the tricarboxylic acid cycle, and heme biosynthesis. In contrast, cobalamin and tetrahydrofolate biosynthesis showed positive correlations. Metatranscriptomic analysis uncovered additional enzyme functions correlated with PD, which were related to galactose metabolism and proteolysis. Our data allowed the proposal of an extended microbial dysbiosis index for peri-implantitis severity. The quantitative index, integrating significant microbial and functional features, revealed high correlation with PD. In conclusion, our results showed that the level of peri-implantitis severity is associated with distinct and significant changes in microbial composition as well as microbial functions. The severity-specific microbiome signatures identified in our study will advance microbiome-based diagnostics and disease stratification, paving the way for targeted clinical interventions for peri-implantitis.

Joshi AA, Szafrański SP, Steglich M. *J Dent Res* 2026;105:313–322. **References:** 40. **Reprints:** Steglich M: Stiesch.Meike@mh-hannover.de—*Carlo Marinello, Switzerland*

Survival and Complication Rates of Feldspathic, Leucite-Reinforced, Lithium Disilicate and Zirconia Ceramic Laminate Veneers: A Systematic Review and Meta-Analysis

Objectives: To analyze survival and complication rates for anterior and premolar laminate-veneers out of different ceramic materials (feldspathic, leucite-reinforced glass-ceramic [LRGC], lithium-disilicate [LDS] and zirconia). ***Materials and Methods***: A systematic literature search was conducted across multiple databases for clinical studies on ceramic laminate-veneers with a minimum-follow-up of ≥ 1 year. The date of last search was on February 19, 2024. Survival, technical, esthetic and biological events were assessed for different laminate-veneer materials at three observation periods (short- [1 to 3 years], mid- [4 to 6 years] and long-term [≥ 7 years])***. Results:*** Twenty-nine studies were included. Meta-analysis revealed a pooled survival-rate of 96.13% for feldspathic, 93.70% for LRGC, and 96.81% for LDS at 10.4 years. No difference was found between materials. Complication rates (technical/esthetic/biological) were as follows: Feldspathic: 41.48%/19.64%/6.51%; LRGC: 29.87%/17.89%/4.4%; LDS: 6.1%/1.9%/0.45% at 10.4 years. Zirconia showed a 100% survival-rate with no complications at 2.6 years. No long-term data was available for zirconia***. Conclusions:*** Feldspathic, LRGC and LDS laminate-veneers showed high survival-rates at long-term observation. LDS slightly outperforms feldspathic and LRGC laminate-veneers with lower long-term complication rates. More studies providing long-term data on zirconia laminate-veneers are needed. Clinical Significance: Ceramic laminate-veneers are a reliable treatment option. LDS may be preferred as a restorative material for long-term success.

Klein P, Spitznagel FA, Zembic A, et al. *J Esthet Restor Dent* 2025;37:601–619. **References:** 69. **Reprints:** Klein P: patrick.klein@med.uni-dusseldorf.de—*Carlo Marinello, Switzerland*

APPENDICES

Appendix Box 1 Electronic Search Strategies

PubMed search strategy

((crowns OR crown OR dental crowns OR crowns, dental OR Denture, Partial, Fixed) OR (crown* OR fixed partial denture* OR FPD OR FPDs OR fixed dental prosthesis OR fixed dental prostheses OR FDP OR FDPs OR bridge*)) AND (Ceramic OR ceramics OR metal ceramic restorations OR ceramic* OR all-ceramic OR Dental Porcelain OR metal-ceramic OR monolithic OR full contour OR veneered) AND (Survival OR survival rate OR survival analysis OR dental restoration failure OR prosthesis failure OR treatment failure)

Embase search strategy

('dental crown'/exp OR 'dental crown' OR (('dental'/exp OR dental) AND ('crown'/exp OR crown)) OR 'fixed partial denture'/exp OR 'fixed partial denture' OR (fixed AND partial AND ('denture'/exp OR denture)) OR 'fixed dental prosthesis'/exp OR 'fixed dental prosthesis' OR (fixed AND ('dental'/exp OR dental) AND ('prosthesis'/exp OR prosthesis)) OR 'bridge'/exp OR bridge OR 'fdp'/exp OR fdp OR fpd) AND ('ceramic'/exp OR ceramic OR (('metal'/exp OR metal) AND ('ceramic'/exp OR ceramic)) OR 'all ceramic' OR 'dental porcelain'/exp OR 'dental porcelain' OR (('dental'/exp OR dental) AND ('porcelain'/exp OR porcelain)) OR 'metal ceramic' OR monolithic OR (full AND ('contour'/exp OR contour)) OR 'full contour' OR veneered) AND ('survival'/exp OR survival OR 'survival rate'/exp OR 'survival rate' OR (('survival'/exp OR survival) AND rate) OR 'survival analysis'/exp OR 'survival analysis' OR (('survival'/exp OR survival) AND ('analysis'/exp OR analysis)) OR 'dental restoration failure'/exp OR 'dental restoration failure' OR (('dental'/exp OR dental) AND ('restoration'/exp OR restoration) AND ('failure'/exp OR failure)) OR 'prosthesis failure'/exp OR 'prosthesis failure' OR (('prosthesis'/exp OR prosthesis) AND ('failure'/exp OR failure)) OR 'treatment failure'/exp OR 'treatment failure' OR (('treatment'/exp OR treatment) AND ('failure'/exp OR failure))) AND [1-1-2014]/sd NOT [5-12-2024]/sd

Cochrane search strategy

((crowns OR crown OR dental crowns OR crowns, dental OR Denture, Partial, Fixed) OR (crown* OR fixed partial denture* OR FPD OR FPDs OR fixed dental prosthesis OR fixed dental prostheses OR FDP OR FDPs OR bridge*)) AND (Ceramic OR ceramics OR metal ceramic restorations OR ceramic* OR all-ceramic OR Dental Porcelain OR metal-ceramic OR monolithic OR full contour OR veneered) AND (Survival OR survival rate OR survival analysis OR dental restoration failure OR prosthesis failure OR treatment failure) in Title Abstract Keyword

Appendix Box 2 Quality-Assessment-Scale for Reconstructive Studies (QAS-RS)

Sample
1. Sample size determination (1 possible answer):
a) sample size was calculated for the primary outcomes of interest.***
b) sample size was calculated but not based on the primary outcomes.**
c) sample size was discussed but not formally calculated.*
d) sample size determination was not reported.
2. Reporting of follow-up frequency (1 possible answer):
a) patients were followed up regularly at predefined intervals throughout the entire observation period.***
b) patients were followed up irregularly during the observation period.**
c) patients were only evaluated at the end of the observation period.*
d) follow-up frequency was not reported.
3. Inclusion and exclusion criteria (1 possible answer):
a) clearly reported, comprehensive, representative for the respective clinical indication.***
b) clearly reported, representative for the respective clinical indication but not comprehensive.**
c) not clearly described.*
d) not reported.
Outcomes
4. Outcomes assessment (1 possible answer):
a) outcomes were clinically evaluated by calibrated examiners using validated methods.***
b) outcomes were clinically evaluated using validated methods, without examiner calibration.**
c) outcomes were clinically evaluated using non-validated methods.*
d) no clinical evaluation was performed.
5. Reporting of failures and complications (1 possible answer):
a) failures and all potential biological and technical complications were reported in detail, including timepoints of occurrence.***
b) failures and all potential biological and technical complications were reported in detail, without specifying detailed timepoints.**
c) failures and some complications were reported, but not all potential biological and technical complications were addressed.*
d) only failures were reported; biological and technical complications were not addressed.
6. Follow-up duration (1 possible answer):
a) mean follow-up period ≥ 5 years, allowing realistic assessment of failures and biological and technical complications.***
b) mean follow-up period between 3 and 5 years.**
c) mean follow-up period ≤ 3 years.*
d) follow-up period not specified.
7. Drop-out rate during follow-up (1 possible answer):
a) less than 3% of subjects lost to follow-up per observation year (e.g. <15% drop-out over 5 years, <30% drop-out over 10 years).***
b) between 3–5% of subjects lost to follow-up per observation year (e.g.15–25% drop-out over 5 years, 30–50% dropout over 10 years).**
c) more than 5% of subjects lost to follow-up per observation year (e.g. >25% drop-out over 5 years, >50% drop-out over 10 years).*
d) drop-out rate not reported.

Grading of Study Quality
0–7 stars: Low quality
8–14 stars: Moderate quality
15–21 stars: High quality
(Maximum achievable score: 21 stars)

Appendix Table 1 Studies Excluded After Full-Text Analysis and Reasons for Exclusion

Reference	Reason for exclusion	Reference	Reason for exclusion	Reference	Reason for exclusion
Abd Alraheam et al. (2023)	1	Goto et al. (2020)	1	Reitemeier et al. (2019)	10
Abdulrahman et al. (2021)	1	Guncu et al. (2022)	2	Rinke et al. (2022)	2
Alfadhli et al. (2022)	1	Gunge et al. (2018)	1	Rinke et al. (2013)	2
Aziz & El-Mowafy (2023)	1	Hansen et al. (2018)	7	Rinke et al. (2016)	1
Aziz et al. (2022)	1	Imburgia et al. (2019)	2	Rinke et al. (2015)	1
Bateli et al. (2014)	1	Jamal et al. (2020)	1	Saleh Samer et al. (2018)	1
Becker et al. (2019)	2	Kabetani et al. (2022)	1	Samer et al. (2017)	2
Behr et al. (2014)	1	Klink et al. (2018)	1	Sarkis-Onofre et al. (2020)	6
Beier & Dumfahrt (2014)	1	Koenig et al. (2024)	8	Sarkis-Onofre et al. (2014)	3
Belleflamme et al. (2017)	1	Koenig et al. (2013)	1	Schmitz & Beani (2016)	1
Boemicke et al. (2014)	1	Kuang et al. (2022)	4	Schmitz et al. (2017)	1
Bömicke et al. (2017)	3	Li et al. (2015)	4	Schneider (2016)	1
Bömicke et al. (2019)	2	Luo et al. (2016)	4	Scutella et al. (2020)	1
Brandt et al. (2019)	1	Machry et al. (2023)	9	Shi et al. (2016)	1
Brignardello-Petersen (2017)	3	Malament et al. (2019)	10	Simeone & Gracis (2015)	1
Cândea et al. (2021)	2	Masaka et al. (2023)	1	Skupien et al. (2016)	3
Carey et al. (2021)	1	Mikeli et al. (2015)	1	Smedberg et al. (2024)	1
Chen et al. (2014)	4	Miura et al. (2018)	1	Tanner et al. (2018)	1
Chen et al. (2021)	4	Miura et al. (2021)	7	Tartaglia et al. (2015)	10
Christensen et al. (2016)	5	Mobilio et al. (2018)	1	Teichmann et al. (2019)	1
D'Souza et al. (2024)	1	Monaco et al. (2013)	1	Teichmann et al. (2017)	10
Datta & Sandhu (2022)	1	Moráguez et al. (2015)	8	Valenti & Valenti (2015)	1
Dhima et al. (2014)	1	Munoz-Sanchez et al. (2021)	2	Valenti et al. (2023)	1
Di Fiore et al. (2023)	1	Naishlos et al. (2022)	1	van den Breemer et al. (2017)	1
Ermatinger et al. (2024)	1	Näpänkangas et al. (2015)	1	van den Breemer et al. (2021)	2
Fabbri et al. (2014)	1	Offer et al. (2022)	1	van den Breemer et al. (2019)	2
Fabbri et al. (2024)	1	Olley et al. (2018)	1	van Erp et al. (2023)	1
Federlin et al. (2014)	2	Otto & Mörmann (2015)	1	Worni et al. (2017)	1
Ferrari Cagidiaco et al. (2020)	2	Oudkerk et al. (2024)	2	Xiao et al. (2022)	4
Ferrari et al. (2017)	6	Overmeer et al. (2016)	1	Yang et al. (2016)	1
Ferrari et al. (2019)	2	Passos Rocha et al. (2021)	10	Ying et al. (2022)	1
Ferrini et al. (2024)	1	Phang et al. (2020)	1	Zhang et al. (2023)	11
Forrer et al. (2020)	1	Pihlaja et al. (2014)	1	Zheng et al. (2015)	3
Fotiadou et al. (2021)	1	Polat et al. (2024)	7	Zürcher et al. (2021)	1
Galli et al. (2024)	1	Pott et al. (2018)	1		
Garcia et al. (2020)	1	Rabel et al. (2024)	1		
Gbadebo et al. (2014)	7	Rauch et al. (2018)	3		
Gherlone et al. (2014)	1	Rauch et al. (2017)	3		
Gonzalez-Bonilla et al. (2024)	1	Reich & Schierz (2013)	3		

1 = No RCT or prospective design; 2 = Does not report on tooth-supported full crowns (partial crowns, onlays, resin-bonded bridges, implant only, tooth-implant splinted); 3 = Duplicate; 4 = Not published in English; 5 = Full-text not available; 6 = No data on survival of restorations; 7 = Follow-up period less than 3 years; 8 = Data not specified between implant and tooth abutments (mixed data); 9 = No clinical examination performed; 10 = Data not specified between crowns & bridges (mixed data); 11 = Retracted article.

Appendix Table 2 Overview of the Included Studies

Study			Patient			Restoration	
Reference	Study design	Setting	Initial (n)	Mean age (n)	Calculated overall drop-out (%)	Initial SCs (n)	SCs anterior (n)
a) Metal-ceramic							
Poletto-Neto et al. (2024)	RCT	University	34	40.5	0.0	34	10
Bacher et al. (2021)	Prospective	NR	19	49	21.1	31	NR
Chaar et al. (2020)	Prospective	University	39	51.8	15.4	60	0
Brondani et al. (2017)	Prospective	University	129	47.8	11.6	152	60
Monaco et al. (2017a)	RCT	University	45	NR	4.2	45	0
Ohlmann et al. (2014)	RCT	University	66‡	46	7.5	40	0
Hey et al. (2014)	Prospective	University	21	49.4	14.3	41	12
Tao et al. (2014)	Prospective	University	100	45.2	16.0	100	100
Reitemeier et al. (2013)	Prospective	Private Practice	95	NR	14.7	190	0
Rinke et al. (2013a)	Prospective	Private Practice	53‡	49.6 ± 9.9	7.5	50	0
Walton (2013)	Prospective	University	670	NR	5.4	2,340	1,197
Vigolo & Mutinelli (2012a)	RCT	Private Practice	20	32	5.0	20	0
Naumann et al. (2011a)	RCT	University	52	44	7.7	52	11
Naumann et al. (2011b)	RCT	University	52	44	7.7	52	11
Gungor et al. (2007)	Prospective	University	260	NR	23.1	260	NR
Marklund et al. (2003)	Prospective	Public Health Service & Private practice	18	51	0.0	42	NR
b) Feldspathic/silica-based ceramic							
Fages et al. (2017)	Prospective	Private practice	323**	NR	NR	212	0
Çehreli et al. (2011a)	RCT	University	12	NR	0.0	50	NR
Burke (2007)	Prospective	University	16	37.5	23.7	59	57
Malament & Socransky (2006a)*	Prospective	Private practice	NR	NR	NR	1,061	NR
Bindl & Mörmann (2004a)	Prospective	University	29‡	53 ± 11	17.0	18	18
Kelsey et al. (1995)	Prospective	University	NR	>19	9.0	101	0
c) Reinforced glass-ceramic (veneered)							
Spehar & Jakovac (2024a)	RCT	Private practice	26	NR	0.0	26	0

Restoration						
SCs posterior (n)	Framework material	Brand name framework material	Manufacturing procedure	Veneering material	Type of cement	Quality assessment
24	Cobalt-chromium alloy	NR	NR	NR	Self-adhesive resin cement	High
NR	Metal (high gold content)	IPS d.SIGN	NR	Leucite ceramic (IPS InLine)	Self-adhesive resin cement	Moderate
60	Gold-platinum, cobalt-chromium	CoCr, Wirobond C+ &bBioPontoStar +, Bego Medical	Laser sintering	Fluor-Apatit-Leucite (IPS d.Sign)	Glass-ionomer cement	Moderate
75	Metal	NR	NR	Ceramic	Resin-cement	Moderate
45	Metal-High noble alloy	IPS d.SIGN 91, Ivoclar Vivadent	Casting & pressing	PoM, Ivoclar Vivadent	Resin-cement	High
37	Metal-gold alloy	IPS d.Sign96, Ivoclar, Vivadent	NR	NR	Hybrid cement	High
29	Titanium	Everest T-Blank	CAD/CAM & veneering	Low-fusing porcelain (Vita Titanium Porcelain)	Zinc phosphate	High
0	Cobalt-chromium alloy	Wirobond C, BEGO	Casting & veneering	Vintage, Shofu	Glass-ionomer cement	Moderate
190	Noble & high noble alloys	Degudent H, BIOcclus 4, Deva 4, Degupal G	NR	Feldspathic ceramic (Duceram)	NR	Moderate
48	Gold	Degunorm	Casting & veneering	Low-fusing porcelain (Duceragold Kiss)	Glass-ionomer	Moderate
1,014	Gold	NR	NR	NR	Zinc phosphate	Moderate
20	Gold	Valcambi	NR	Noritake EX-3	Glass-ionomer	Moderate
37	Gold	AGC	Galvano-formed	AGC	Zinc phosphate	High
37	High noble alloy	Degunorm	NR	Duceragold Kiss	Zinc phosphate	High
NR	Metal	Probond	Probond system	NR	Glass-ionomer cement	Moderate
NR	Gold & titanium	MK-100, gold alloy, Ti-Pro	Casting & veneering	Low fusing ceramic (Procera ceramic) & medium fusing ceramic (Ivoclar classic)	NR	Moderate
212	Feldspar ceramic	Vita Mark II, Vita Zahnfabrik	CAD/CAM	NA	Self adhesive resin cement	Moderate
NR	Feldspathic	Noritake	Refractory die & veneering	Feldspathic	Resin-cement	Moderate
2	Feldspathic porcelain	NR	Refractory die & veneering	Feldspathic porcelain	Resin-cement	Moderate
NR	Glass-ceramic	Dicor	NR	NR	Resin cement, glass-ionomer	Moderate
0	Feldspar ceramic	Vitablocs Mk II	CAD/CAM	NA	Resin-cement	Moderate
101	Glass-ceramic	Dicor	Casting & veneering	NR	Resin-cement	High
26	Lithium disilicate	IPSe.max CAD, Ivoclar Vivadent	CAD/CAM & veneering	IPS e.max Ceram, Ivoclar Vivadent	Dual-cure resin-cement	High

Appendix Table 2 Overview of the Included Studies (cont)

Study			Patient			Restoration	
Reference	Study design	Setting	Initial (n)	Mean age (n)	Calculated overall drop-out (%)	Initial SCs (n)	SCs anterior (n)
Margvelashvili-Malament et al. (2024a)	Prospective	Private practice	53‡	60	NR	264	264
Teichmann et al. (2017)	Prospective	University	45	32.9	17.8	106	38
Huettig & Gehrke (2016a)	Prospective	University	58‡	43	22.4	202	176
Toman & Toksavul (2015)	Prospective	University	35	NR	2.9	125	98
Gehrt et al. (2013)	Prospective	University	41	34	9.8	104	82
Malament & Socransky (2006b)*	Prospective	Private practice	NR	NR	NR	954	NR
Marquardt & Strub (2005)	Prospective	University	43**	39.9	0.0	27	0
Sorensen et al. (1998)	Prospective	University	33	NR	0.0	75	47
Studer et al. (1998)	Prospective	University	71	NR	17.0	142	67
d) Reinforced glass-ceramic (monolithic)							
Spehar & Jakovac (2024b)	RCT	Private practice	26	NR	3.8	26	0
Margvelashvili-Malament et al. (2024b)	Prospective	Private practice	53‡	60	NR	287	0
Rauch et al. (2023)	Prospective	University & private practice	34	46.5	17.6	34	0
Hammoudi et al. (2022a)	RCT	University & specialised clinic	32‡	43	0.0	362	NR
Le et al. (2022a)	RCT	University & private practice	71‡	66	7.0	30	0
Kasem et al. (2022a)	RCT	University	10	30	10.0	20	0
Gardell et al. (2021a)	RCT	Specialised clinic	43‡	NR	0.0	29	0
Seidel et al. (2020a)	RCT	University	15	NR	6.7	15	0
Lundgren et al. (2018a)	RCT	Specialist clinic	27‡	17.9	0.0	108	NR
Huettig & Gehrke (2016b)	Prospective	University	58‡	43	22.4	173	0
Cortellini & Canale (2012)	Prospective	Private practice	76	36	0.0	22	NR
e) Glass-infiltrated alumina							
Çehreli et al. (2011b)	RCT	University	21	NR	0.0	51	NR
Kokubo et al. (2011)	Prospective	University	39	50.9	12.8	101	NR

	Restoration						
	SCs posterior (n)	Framework material	Brand name framework material	Manufacturing procedure	Veneering material	Type of cement	Quality assess-ment
	0	Lithium disilicate	IPS e.max Press, Ivoclar Vivadent	Pressing & veneering	NR	NR	Moderate
	49	Lithium disilicate	IPS e.max Press, Ivoclar Vivadent	Pressing & veneering	IPS Eris for E2, Ivoclar Vivadent	Resin & glass-ionomer cement	High
	0	Lithium disilicate	IPS E.Max Press, Ivoclar Vivadent	Pressing & veneering	Feldspathic ceramic	Resin-cement	Moderate
	23	Lithium disilicate	IPS Empress 2, Ivoclar, Vivadent	Pressing & veneering	Fluorapatite veneering ceramic	Dual-cure resin-cement	High
	22	Lithium disilicate	IPS e.max Press, Ivoclar, Vivadent	Pressing & veneering	Fluorapatite (Ivoclar)	Resin & glass-ionomer cement	High
	NR	Leucite-glass ceramic	NR	NR	NR	NR	Moderate
	27	Lithium disilicate	IPS Empress 2	Heat pressed & veneering	Apatite sintered glass-ceramic	Resin-cement	Moderate
	28	Leucite-glass ceramic	IPS Empress system	Heat pressed & veneering	NR	Resin-cement	Moderate
	75	Leucite-glass ceramic	IPS Empress	Heat pressed + veneering	Feldspathic porcelain	Resin-cement & zinc phosphate	Moderate
	26	Lithium disilicate	IPSe.max CAD, Ivoclar Vivadent	CAD/CAM	NA	Dual-cure resin-cement	High
	287	Lithium disilicate	IPS e.max Press, Ivoclar Vivadent	Pressing	NA	NR	Moderate
	34	Lithium disilicate	IPS e.max CAD LT, Ivoclar Vivadent	CAD/CAM	NA	Dual-cure self-adhesive resin-cement	High
	NR	Lithium disilicate	IPS e.max Press, Ivoclar Vivadent AG	Pressing	NA	Self-etching resin-cement	Moderate
	30	Lithium disilicate	IPS e.max CAD, Ivoclar Vivadent AG	NR	NA	Dual-cure resin-cement	High
	20	Zir-reinforced Lithium silicate	Celtra Duo, Dentsply Sirona	CAD/CAM	NA	Dual-cure self-adhesive resin-cement	High
	29	Lithium disilicate	NR	CAD/CAM	NA	Dual-cure resin-cement	High
	14	Lithium disilicate	IPSe.max CAD, Ivoclar Vivadent	CAD/CAM	NA	Resin-cement	Moderate
	NR	Lithium disilicate	IPS e.max Press, Ivoclar Vivadent	Pressing	NA	Resin-cement	Moderate
	151	Lithium disilicate	IPS E.Max Press, Ivoclar Vivadent	Pressing	NA	Resin-cement	Moderate
	NR	Lithium disilicate	e.max CAD, e.max Press	CAD/CAM, pressed	NA	Resin-cement	Moderate
	NR	Glass-infiltrated alumina	In-Ceram Alumina	Slip casting & veneering	Feldspar ceramic (Vitadur Alpha)	Resin-cement	Moderate
	NR	Glass-infiltrated alumina	In-Ceram Alumina	CAD/CAM & veneering	Feldspar ceramic (Vitadur Alpha)	Resin & glass-ionomer cement	High

Appendix Table 2 Overview of the Included Studies (cont)

Study			Patient			Restoration	
Reference	Study design	Setting	Initial (n)	Mean age (n)	Calculated overall drop-out (%)	Initial SCs (n)	SCs anterior (n)
Malament & Socransky (2006c)*	Prospective	Private practice	NR	NR	NR	312	NR
Bindl & Mörmann (2004b)	Prospective	University	29‡	53 ± 11	17.0	18	18
Bindl & Mörmann (2002)	Prospective	University	21	NR	NR	43	0
McLaren & White (2000)	Prospective	Private practice	107	NR	10.0	223	NR
Scotti et al. (1995)	Prospective	University & private practice	45	44.2	0.0	63	25
Hüls (1995)	Prospective	University	92	44.2	11.0	335	NR
f) Densely sintered alumina							
Vanoorbeek et al. (2010)	RCT	University	130‡	NR	24.5	141	65
Kokubo et al. (2009)	Prospective	University	57	46.4	19.3	101	NR
Walter el al. (2005)	Prospective	University	70	38.8	6.0	107	61
Ödman & Andersson (2001)	Prospective	Private practice	50	53	18.0	87	23
Oden et al. (1998)	Prospective	University & private practice	58	NR	3.0	100	17
g) Densely sintered zirconia (veneered)							
Prause et al. (2022)	Prospective	NR	28	51	32.1	36	2
Torres et al. (2021)	RCT	NR	30	NR	33.3	60	20
Serra-Pastor et al. (2021)	Prospective	University	34	NR	20.3	74	74
Seidel et al. (2020b)	RCT	University	15	NR	6.7	15	0
Cagidiaco et al. (2019)	RCT	University	50	45.7	0.0	50	0
Cantner et al. (2019)	Prospective	Private practice	118**	NR	NR	106	0
Lundgren et al. (2018b)	RCT	Specialist clinic	27‡	17.9	0.0	119	NR
Dogan et al. (2017)	Prospective	University	18	44.5	5.6	20	20
Monaco et al. (2017b)	RCT	University	45	NR	4.2	45	0
Güncü et al. (2016)	Prospective	University & private practice	24	44.1	0.0	24	0

Restoration						
SCs posterior (n)	Framework material	Brand name framework material	Manufacturing procedure	Veneering material	Type of cement	Quality assess-ment
NR	NR	In-Ceram	NR	NR	NR	Moderate
0	Glass-infiltrated alumina	In-Ceram Spinell	CAD/CAM & veneering	Feldspar ceramic (Vita-dur Alpha)	Resin-cement	Moderate
43	Glass-infiltrated alumina	In-Ceram Alumina & In-Ceram Spinell	CAD/CAM & veneering	Feldspar ceramic (Vita-dur Alpha)	Resin-cement	Moderate
NR	Glass-infiltrated alumina	In-Ceram Alumina	Slip casting & veneering	NR	Resin cement, resin-modified glass-ionomer, glass-ionomer & zinc-phosphate	Moderate
38	Glass-infiltrated alumina	In-Ceram Alumina	Slip casting & veneering	Feldspar ceramic (Vitadur-N)	Glass-ionomer cement	Moderate
NR	Glass-infiltrated alumina	In-Ceram Alumina	Slip casting & veneering	Feldspar ceramic	NR	Low
76	Densely sintered Al2O3	GN-1	CAD/CAM & veneering	GC Initial AL	Resin-cement	Moderate
NR	Densely sintered Al2O3	Procera	CAD/CAM & veneering	Veneering porcelain (Vitadur Alpha)	Resin-cement	High
46	Densely sintered Al2O3	Procera	CAD/CAM & veneering	NR	Glass-ionomer cement	Moderate
64	Densely sintered Al2O3	Procera AllCeram	CAD/CAM & veneering	Feldspar ceramic (Vitadur-N)	Zinc phosphate & glass-ionomer cement	High
83	Densely sintered Al2O3	Procera AllCeram	CAD/CAM & veneering	Feldspar ceramic (Vitadur-N)	Zinc phosphate & glass-ionomer cement	Moderate
26	Zirconia	Cercon Base & Base Colored, DeguDent	CAD/CAM & veneering	Cercon Ceram Kiss	Zinc oxide phosphate	Moderate
40	Zirconia	Cercon Base, Dentsply Sirona	CAD/CAM & pressing	Cercon Ceram Press, Dentsply Sirona	Resin & glass-ionomer cement	High
0	Zirconia	Lava Frame Zirconia, 3M ESPE	CAD/CAM & veneering	Lava Ceram, 3M ESPE	Glass-ionomer cement	Moderate
14	Zirconia	Nobel Procera, Nobel Biocare	CAD/CAM & veneering	Fuorapatite glass- ceramic (IPS e.max Ceram, Ivoclar Vivadent)	Glass-ionomer cement	Moderate
50	Zirconia	NR	CAD/CAM & veneering	Feldspathic (Initial Zr-FS, GC)	Glass-ionomer cement	Moderate
106	Zirconia	IPS e.max ZirCAD, Ivoclar Vivadent	CAD/CAM & pressing	Lithium disilicate (IPS e.max press, Ivoclar Vivadent)	Resin-modified glass-ionomer cement	Moderate
NR	Zirconia	Procera, Nobel Biocare	CAD/CAM & veneering	Vita Porcelain	Resin-cement	Moderate
0	Zirconia	NR	CAD/CAM & veneering	Porcelain (Lava CeramS)	Resin-cement	High
45	Zirconia	ZirCad, Ivoclar Vivadent	CAD/CAM + pressing	ZirPress, Ivoclar Vivadent	Resin-cement	High
24	Zirconia	Lava, 3M, ESPE	CAD/CAM & veneering	Feldspathic porcelain (Vita VM9, Vita Zahnfabrik)	Resin-modified glass-ionomer cement	High

Appendix Table 2 Overview of the Included Studies (cont)

Study			Patient			Restoration	
Reference	Study design	Setting	Initial (n)	Mean age (n)	Calculated overall drop-out (%)	Initial SCs (n)	SCs anterior (n)
Ferrari et al. (2015)	RCT	University	56	43.6	0.0	90	0
Rinke et al. (2013b)	Prospective	Private practice	53‡	49.6 ± 9.9	7.5	55	0
Sagirkaya et al. (2012)	RCT	University	42**	NR	0.0	74	NR
Vigolo & Mutinelli (2012b)	RCT	Private practice	20	32	5.0	20	0
Vigolo & Mutinelli (2012c)	RCT	Private practice	20	32	0.0	20	0
Beuer et al. (2010)	Prospective	University	38**	50.9	0.0	50	15
Schmitt et al. (2010)	Prospective	University	10	42.1	10.0	19	19
h) Densely sintered zirconia (monolithic & microveneered)							
Gseibat et al. (2023)	Prospective	University	24	55.3	0.0	30	0
Barile et al. (2023)	Prospective	University	31	61	0.0	34	0
Waldecker et al. (2022a)	Prospective	University	68‡	59.7	4.4	90	3
Waldecker et al. (2022b)	Prospective	University	68‡	62.8	4.4	72	45
Le et al. (2022b)	RCT	University & private practice	71‡	65	7.0	30	0
Le et al. (2022c)	RCT	University & private practice	71‡	66	7.0	30	0
Hammoudi et al. (2022b)	RCT	University & specialised clinic	32‡	46.6	6.3	351	NR
Kasem et al. (2022b)	RCT	University	14	30	7.1	20	0
Gardell et al. (2021b)	RCT	Specialised clinic	43‡	NR	0.0	30	0
Solá-Ruíz et al. (2021)	Prospective	University	50	NR	0.0	50	0
i) Zirconium silicate ($ZrSiO_4$)							
Passia et al. (2013)	RCT	University	123	42.7	37.4	123	0

* Update from 2006 based on personal communication with the senior author.
‡ Including patients who received crowns of different materials/designs
** Including patients who received both tooth-supported crowns and other types of restorations (e.g., implant-supported crowns, endocrowns, tooth-supported multiple-unit fixed dental prostheses)

Restoration						
SCs posterior (n)	Framework material	Brand name framework material	Manufacturing procedure	Veneering material	Type of cement	Quality assess-ment
90	Zirconia	NR	CAD/CAM & veneering (pressure layering technique)	Porcelain (Initial Zr-FS)	Self adhesive resin cement	Moderate
51	Zirconia	Cercon Smart ceramics	CAD/CAM & veneering	Cercon Ceram-Kiss	Glass-ionomer cement	Moderate
NR	Zirconia	ZirkonZahn, Cercon, Lava, Katana	CAD/CAM, copy-milling + veneering	NR	Resin-cement	Moderate
20	Zirconia	Procera	CAD/CAM & veneering	NobelRondo	Glass-ionomer cement	Moderate
20	Zirconia	Lava	CAD/CAM & veneering	Lava Ceram	Glass-ionomer cement	Moderate
35	Zirconia	IPS e.max ZirCAD	CAD/CAM & veneering	Fuorapatite glass- ceramic (IPS e.max Ceram, Ivoclar Vivadent)	Glass-ionomer cement	Moderate
0	Zirconia	Lava	CAD/CAM veneering	Lava Ceram	Glass-ionomer cement	Moderate
30	Zirconia	Katana Zirconia STML, Kuraray Europe	CAD/CAM	NA	Self-adhesive resin-cement	High
34	Zirconia	Biodynamic Zirconium Multilayer 1200/600 Mpa Progressive, Biodynamic	CAD/CAM	NA	Self-adhesive resin-cement	Moderate
83	Zirconia	Cercon ht, DeguDent	CAD/CAM	NA	Glass-ionomer & resin-cement	High
27	Zirconia	Cercon ht, DeguDent	CAD/CAM & micro-veneering	Cercon Ceram Kiss, DeguDent	Glass-ionomer & resin cement	High
28	Zirconia	BruxZir, Glidewell	CAD/CAM	NA	Dual-cure resin cement	High
26	Zirconia	BruxZir, Glidewell	CAD/CAM & micro-veneering	Feldspathic (GC Initial Zr-FS)	Dual-cure resin cement	High
NR	Zirconia	BruxZir Solid Zirconia, Glidewell Laboratories	CAD/CAM & micro-veneering	NR	Self-etching resin cement	Moderate
20	Zirconia	Katana, Kuaray Nortikate	CAD/CAM	NA	Dual cure self-adhesive resin cement	High
30	Zirconia	NR	CAD/CAM	NA	Dual cure resin-cement	High
50	Zirconia	Lava Frame Zirconia, 3M ESPE	CAD/CAM	NA	Resin-cement	High
123	Zirconium Silicate	KaVo shrinkage free	CAD/CAM	NA	Glass-ionomer cement	Moderate

Appendix Table 3 Summary of Annual Failure Rates, Relative Failure Rates, and Survival Estimates for SCs with Metal-Ceramic SCs as Reference

Type of SC	Total no. of SCs	Total exposure time, years	Mean follow-up time, years	Estimated annual failure rate* (95% CI)	5-year survival summary estimate* (95% CI)	Relative failure rate** (95% CI)	*P***
Metal-ceramic	3,509	33,738	9.6	0.59 (0.43–0.80)	97.1% (96.1%–97.9%)	1.00 (Ref.)	
Feldspathic/silica-ceramic	1,501	10,167	6.8	2.02 (1.67–2.44)	90.4% (88.5%–92.0%)	3.44 (2.42–4.88)	< .0001
Reinforced glass-ceramic, veneered	2,025	9,926	4.9	0.88 (0.51–1.51)	95.7% (92.7%–97.5%)	1.49 (0.82–2.73)	.192
Reinforced glass-ceramic, monolithic	1,106	5,111	4.6	0.29 (0.13–0.66)	98.5% (96.8%–99.3%)	0.50 (0.22–1.15)	.103
Glass-infiltrated alumina	1,146	5,091	4.4	1.18 (0.78–1.80)	94.3% (91.4%–96.2%)	2.01 (1.22–3.30)	.006
Densely sintered alumina	536	2,564	4.8	1.13 (0.78–1.65)	94.5% (92.1%–96.2%)	1.92 (1.22–3.04)	.005
Densely sintered zirconia, veneered	877	3,808	4.3	0.55 (0.33–0.93)	97.3% (95.5%–98.4%)	0.94 (0.52–1.70)	.838
Densely sintered zirconia, monolithic	737	2,584	3.5	0.66 (0.28–1.54)	96.8% (92.6%–98.6%)	1.12 (0.47–2.66)	.796

*Based on robust Poisson regression.
**Based on multivariable robust Poisson regression including all types of SCs.

Appendix Table 4 Annual Failure Rates and Estimated 5-Year Survival According to Position in the Mouth

Type of SC	Anterior: Total no. of SCs	Anterior: Estimated annual failure rate (95% CI)	Anterior: 5-year survival summary estimate* (95% CI)	Posterior: Total no. of SCs	Posterior: Estimated annual failure rate (95% CI)	Posterior: 5-year survival summary estimate* (95% CI)	*P**
Metal-ceramic	110	4.29* (2.27–8.08)	80.7%* (66.7%–89.3%)	234	1.13* (0.46–2.76)	94.5%* (87.1%–97.7%)	.008
Feldspathic/silica-based ceramic	1,056	0.91* (0.09–0.93)	95.5%* (95.4%–95.7%)	1,807	2.25* (1.84–2.76)	89.4%* (87.1%–91.2%)	< .0001
Reinforced glass-ceramic, veneered	705	0.52* (0.09–3.18)	97.4%* (85.3%–99.6%)	175	1.71* (0.86–3.41)	91.8%* (84.3%–95.8%)	.201
Reinforced glass-ceramic, monolithic	0	NA	NA	591	0.35* (0.12–0.99)	98.3%* (95.2%–99.4%)	NA
Glass-infiltrated alumina	43	0.69* (0.09–5.65)	96.6%* (75.4%–99.6%)	81	1.54* (0.69–3.42)	92.6%* (84.3%–96.6%)	.395
Densely sintered alumina	101	0.67* (0.36–1.24)	96.7%* (94.0%–98.2%)	193	1.13* (0.64–2.00)	94.5%* (90.5%–96.9%)	.171
Densely sintered zirconia, veneered	128	0.34 * (0.15–0.78)	98.3%* (96.2%–99.3%)	455	0.61* (0.32–1.13)	97.0%* (94.5%–98.4%)	.250
Densely sintered zirconia, monolithic	0	NA	NA	218	0.58* (0.28–1.23)	97.1%* (94.0%–98.6%)	NA

NA = not analyzed.
*Based on robust Poisson regression.

Appendix Table 5 Relative Complication Rates for Different Types of SCs

Failure/complication	Metal-ceramic	Feldspathic/silica-based ceramic		Reinforced glass-ceramic – veneered		Reinforced glass-ceramic – monolithic	
		Relative compl. rate*	*P*-value*	Relative compl. rate*	*P*-value*	Relative compl. rate*	*P*-value*
Total number of SCs experiencing biologic complications	1.00 (Ref.)	n.a.	n.a.	3.04 (1.36-6.78)	p=0.007	1.69 (0.73-3.93)	p=0.222
Caries on abutments	1.00 (Ref.)	0	p<0.0001	0.33 (0.06-1.87)	p=0.213	0.75 (0.14-4.15)	p=0.742
SCs lost due to caries	1.00 (Ref.)	0	p<0.0001	1.09 (0.25-4.75)	p=0.908	1.75 (0.45-6.80)	p=0.413
SCs lost due to endodontic failures	1.00 (Ref.)	0	p<0.0001	0.33 (0.07-1.54)	p=0.159	0.12 (0.02-0.82)	p=0.030
SCs lost due to abutment tooth fracture	1.00 (Ref.)	0.96 (0.18-5.03)	p=0.958	0.37 (0.09-1.56)	p=0.174	0.44 (0.67-2.87)	p=0.390
Total number of SCs experiencing technical complications	1.00 (Ref.)	n.a.	n.a.	17.6 (3.46-89.60)	p=0.001	8.59 (1.50-49.39)	p=0.016
Total number of ceramic chippings or fractures	1.00 (Ref.)	0.63 (0.18-2.17)	p=0.461	1.04 (0.42-2.54)	p=0.938	0.31 (0.09-1.02)	p=0.054
Failure due to core fracture	1.00 (Ref.)	0.63 (0.18-2.17)	p=0.461	1.04 (0.42-2.54)	p=0.938	0.31 (0.09-1.02)	p=0.054
Minor ceramic chippings - polished	1.00 (Ref.)	0.70 (0.10-5.04)	p=0.721	1.13 (0.26-4.88)	p=0.870	0.08 (0.01-0.46)	p=0.005
Major ceramic chippings – repaired	1.00 (Ref.)	0	p<0.0001	0	p<0.0001	0.15 (0.02-1.04)	p=0.055
Failure due to catastrophic veneering ceramic fracture	1.00 (Ref.)	11.27 (2.72-46.72)	p=0.001	5.22 (1.12-24.40)	p=0.036	1.93 (0.27-13.78)	p=0.512
Loss of retention	1.00 (Ref.)	2.09 (0.16-27.3)	p=0.575	4.4 (0.60-32.5)	p=0.146	3.76 (0.62-22.81)	p=0.150
SCs remade due to esthetic issues	1.00 (Ref.)	0	p<0.0001	0	p<0.0001	0	p<0.0001
Marginal discoloration	1.00 (Ref.)	6.19 (1.13-34.1)	p=0.036	6.16 (1.20-31.7)	p=0.030	30.00 (5.15-174.2)	p<0.0001

*Based on multivariable robust Poisson regression including all types of SCs with metal-ceramic SCs as reference.

Glass-infiltrated Alumina		Densely sintered alumina		Densely sintered zirconia – veneered		Densely sintered zirconia – monolithic		Zirconia silicate	
Relative compl. rate*	*P*-value*	Relative compl. rate*	*P*-value*	Relative compl. rate*	*P*-value*	Relative compl. rate*	*P*-value*	Relative compl. rate*	*P*-value*
6.76 (5.11-8.94)	p<0.0001	n.a.	n.a.	1.70 (0.96-2.87)	p=0.330	2.07 (0.73-5.86)	p=0.170	n.a.	n.a.
2.98 (0.61-14.47)	p=0.175	1.17 (0.18-7.45)	p=0.870	0.33 (0.05-2.12)	p=0.243	0.92 (0.14-5.98)	p=0.934	7.15 (1.99-25.7)	p=0.003
0.60 (0.13-2.65)	p=0.492	1.31 (0.45-3.88)	p=0.618	0	p<0.0001	1.96 (0.53-7.26)	p=0.314	n.a.	n.a.
0	p<0.0001	0	p<0.0001	0.19 (0.05-0.80)	p=0.023	0.53 (0.18-1.53)	p=0.238	0.70 (0.46-1.08)	p=0.108
0.53 (0.21-1.30)	p=0.163	0.39 (0.06-2.49)	p=0.320	0.30 (0.08-1.15)	p=0.079	0.78 (0.36-1.68)	p=0.519	n.a.	n.a.
46.14 (9.83-216.64)	p<0.0001	n.a.	n.a.	11.53 (2.17-61.37)	p=0.004	9.57 (1.74-52.73)	p=0.009	n.a.	n.a.
1.66 (0.51-5.39)	p=0.397	0.46 (0.19-1.13)	p=0.092	1.43 (0.55-3.78)	p=0.459	0.07 (0.02-0.25)	p<0.0001	5.62 (2.56-12.38)	p<0.0001
1.66 (0.51-5.39)	p=0.397	0.46 (0.19-1.13)	p=0.092	1.43 (0.55-3.78)	p=0.459	0.07 (0.02-0.25)	p<0.0001	5.62 (2.56-12.38)	p<0.0001
1.49 (0.31-7.21)	p=0.619	0.69 (0.15-3.23)	p=0.638	1.48 (0.29-7.53)	p=0.630	0.12 (0.02-0.66)	p=0.015	n.a.	n.a.
0.61 (0.15-2.38)	p=0.473	0.37 (0.06-2.29)	p=0.288	0.57 (0.12-2.65)	p=0.469	0	p<0.0001	n.a.	n.a.
6.92 (1.04-45.95)	p=0.045	6.95 (1.72-28.11)	p=0.007	5.30 (1.16-24.2)	p=0.031	0	p<0.0001	n.a.	n.a.
5.56 (1.17-26.37)	p=0.031	20.24 (3.21-127.6)	p=0.001	4.66 (0.80-27.27)	p=0.088	16.86 (3.75-75.85)	p<0.0001	n.a.	n.a.
1.65 (0.64-4.22)	p=0.293	1.29 (0.32-5.23)	p=0.726	0	p<0.0001	0	p<0.0001	n.a.	n.a.
36.6 (7.86-170.1)	p<0.0001	0	p<0.0001	4.28 (0.66-27.6)	p=0.127	155.9 (44.7-543.7)	p<0.0001	n.a.	n.a.

Appendix Table 6 Comparison of Annual Failure and Complication Rates for Veneered and Monolithic Reinforced Glass-Ceramic SCs

	Veneered reinforced glass-ceramic SCs		Monolithic reinforced glass-ceramic SCs		
Failure/complication	Total no. of SCs	Estimated annual failure rate* (95% CI)	Total no. of SCs	Estimated annual failure rate* (95% CI)	*P*
Number of failures	1,071	0.88 (0.51–1.51)	1,106	0.29 (0.13–0.66)	.021
Total number of biologic complications	412	1.27* (0.52–3.16)	650	0.71* (0.30–1.68)	.314
Caries on abutments	559	0.08* (0.02–0.27)	819	0.17* (0.05–0.57)	.340
SCs lost due to caries	1,071	0.06* (0.01–0.29)	819	0.10* (0.03–0.40)	.632
SCs lost due to endodontic failures	827	0.10* (0.02–0.49)	819	0.03* (0.005–0.25)	.413
SCs lost due to abutment tooth fracture	929	0.07* (0.02–0.33)	711	0.09* (0.01–0.62)	.882
Total number of technical complications	438	1.37* (0.77–2.43)	696	0.67* (0.28–1.58)	.154
Total number of ceramic chippings or fractures	638	1.18* (0.74–1.88)	711	0.35* (0.13–0.91)	.021
Failure due to core fracture	1,071	0.42* (0.14–1.30)	685	0.14* (0.04–0.46)	.167
Minor ceramic chippings: polished	436	0.77* (0.51–1.16)	538	0.05* (0.02–0.16)	< .0001
Major ceramic chippings: repaired	436	0	538	0.05* (0.007–0.39)	< .0001
Failure due to catastrophic veneering ceramic fracture	929	0.24* (0.10–0.55)	711	0.09* (0.02–0.41)	.251
Loss of retention	777	0.16* (0.03–0.87)	1,091	0.13* (0.04–0.53)	.880
SCs remade due to esthetic issues	721	0	755	0	NA
Marginal discoloration	357	0.67* (0.21–2.15)	234	3.27* (0.86–12.45)	.065

NA = not analyzed.
*Based on robust Poisson regression.

Appendix Table 7 Comparison of Annual Failure and Complication Rates for Veneered and Monolithic Densely Sintered Zirconia Ceramic SCs

	Veneered zirconia ceramic SCs		Monolithic zirconia ceramic SCs		
Failure/complication	Total no. of SCs	Estimated annual failure rate* (95% CI)	Total no. of SCs	Estimated annual failure rate* (95% CI)	*P*
Number of failures	877	0.55 (0.33–0.93)	737	0.66 (0.28–1.54)	.721
Total number of biologic complications	273	0.25* (0.09–0.72)	717	0.87* (0.30–2.48)	.089
Caries on abutments	572	0.08* (0.02–0.31)	687	0.21* (0.05–0.89)	.301
SCs lost due to caries	841	0	737	0.12* (0.03–0.43)	< .0001
SCs lost due to endodontic failures	841	0.06* (0.01–0.23)	737	0.15* (0.06–0.43)	.245
SCs lost due to abutment tooth fracture	781	0.06* (0.02–0.23)	737	0.15* (0.07–0.33)	.224
Total number of technical complications	193	0.90* (0.44–1.85)	703	0.74* (0.35–1.58)	.710
Total number of ceramic chippings or fractures	570	1.64* (0.92–2.92)	703	0.08* (0.03–0.22)	< .0001
Failure due to core fracture	841	0.17* (0.07–0.42)	737	0	< .0001
Minor ceramic chippings: polished	534	1.02* (0.45–2.32)	703	0.08* (0.03–0.22)	< .0001
Major ceramic chippings: repaired	534	0.20* (0.05–0.91)	737	0	< .0001
Failure due to catastrophic veneering ceramic fracture	781	0.24* (0.11–0.52)	737	0	< .0001
Loss of retention	540	0.17* (0.05–0.62)	737	0.62* (0.26–1.45)	.094
SCs remade due to esthetic issues	561	0	465	0	NA
Marginal discoloration	448	0.47* (0.11–1.99)	30	17.0* (10.22–25.82)	< .0001

NA = not analyzed.
*Based on robust Poisson regression.

Appendix Table 8 Quality-Assessment-Scale for Reconstructive Studies (QAS-RS) of the Included Studies

	Sample			Outcomes					
Reference	Sample size determination	Reporting of follow-up frequency	Inclusion and exclusion criteria	Outcome assessment	Reporting of failures and complications	Follow-up duration	Dropout rate during follow-up	Total (maximum 21)	Overall quality assessment
a) Metal-ceramic									
Poletto-Neto et al. (2024)	1	3	2	3	1	3	3	16	High
Bacher et al. (2021)	0	2	2	1	0	3	3	11	Moderate
Chaar et al. (2020)	0	3	2	1	2	3	3	14	Moderate
Brondani et al. (2017)	1	3	2	1	1	1	1	10	Moderate
Monaco et al. (2017a)	1	3	2	3	3	2	3	17	High
Ohlmann et al. (2014)	1	3	2	2	2	2	3	15	High
Hey et al. (2014)	0	3	3	1	2	3	3	15	High
Tao et al. (2014)	0	3	2	3	1	1	1	11	Moderate
Reitemeier et al. (2013)	0	3	2	1	1	3	3	13	Moderate
Rinke et al. (2013a)	0	3	2	1	2	2	3	13	Moderate
Walton (2013)	1	1	3	1	1	3	3	13	Moderate
Vigolo & Mutinelli (2012a)	0	3	1	3	1	2	3	13	Moderate
Naumann et al. (2011a)	1	3	2	3	2	2	3	16	High
Naumann et al. (2011b)	1	3	2	3	2	2	3	16	High
Gungor et al. (2007)	0	3	2	3	1	3	2	14	Moderate
Marklund et al. (2003)	0	3	1	3	1	2	3	13	Moderate
b) Feldspathic/silica-based ceramic									
Fages et al. (2017)	0	3	2	1	1	2	0	9	Moderate
Çehreli et al. (2011a)	0	3	2	2	1	2	3	13	Moderate
Burke (2007)	0	3	1	2	2	2	1	11	Moderate
Malament & Socransky (2006a)	0	3	2	1	0	3	0	9	Moderate
Bindl & Mörmann (2004a)	0	3	2	3	1	2	2	13	Moderate
Kelsey et al. (1995)	1	3	2	3	1	2	3	15	High
c) Reinforced glass-ceramic (veneered)									
Spehar & Jakovac (2024a)	1	3	2	2	2	2	3	15	High
Margvelashvili-Malament et al. (2024a)	0	3	2	1	0	3	0	9	Moderate
Teichmann et al. (2017a)	0	3	2	3	1	3	3	15	High
Huettig & Gehrke (2016a)	0	3	1	2	1	2	1	10	Moderate
Toman & Toksavul (2015)	0	3	2	3	2	3	3	16	High
Gehrt et al. (2013)	0	3	2	1	3	3	3	15	High
Malament & Socransky (2006b)	0	3	2	1	0	3	0	9	Moderate
Marquardt & Strub (2005)	0	3	2	1	1	2	3	12	Moderate
Sorensen et al. (1998)	0	3	1	1	2	2	3	12	Moderate
Studer et al. (1998)	0	3	2	3	1	3	2	14	Moderate

Appendix Table 8 Quality-Assessment-Scale for Reconstructive Studies (QAS-RS) of the Included Studies *(cont)*

	Sample			Outcomes					
Reference	Sample size determination	Reporting of follow-up frequency	Inclusion and exclusion criteria	Outcome assessment	Reporting of failures and complications	Follow-up duration	Dropout rate during follow-up	Total (maximum 21)	Overall quality assessment
d) Reinforced glass-ceramic (monolithic)									
Spehar & Jakovac (2024b)	1	3	2	2	2	2	3	15	High
Margvelashvili-Malament et al. (2024b)	0	3	2	1	0	3	0	9	Moderate
Rauch et al. (2023)	0	2	2	3	3	3	3	16	High
Hammoudi et al. (2022a)	0	2	2	3	2	1	3	13	Moderate
Le et al. (2022a)	0	3	2	3	2	2	3	15	High
Kasem et al. (2022a)	0	3	2	3	3	2	2	15	High
Gardell et al. (2021a)	1	3	2	3	2	2	3	16	High
Seidel et al. (2020a)	0	3	2	2	1	1	3	12	Moderate
Lundgren et al. (2018a)	0	2	2	2	1	3	3	13	Moderate
Huettig & Gehrke (2016b)	0	3	1	2	1	2	1	10	Moderate
Cortellini & Canale (2012)	0	3	3	1	2	2	3	14	Moderate
e) Glass-infiltrated alumina									
Çehreli et al. (2011b)	0	3	2	2	1	2	3	13	Moderate
Kokubo et al. (2011)	0	3	2	3	2	2	3	15	High
Malament & Socransky (2006c)	0	3	2	1	0	3	0	9	Moderate
Bindl & Mörmann (2004b)	0	3	2	3	1	2	2	13	Moderate
Bindl & Mörmann (2002)	0	1	1	3	1	2	0	8	Moderate
McLaren & White (2000)	0	3	2	1	1	2	3	12	Moderate
Scotti et al. (1995)	0	3	3	1	1	2	3	13	Moderate
Hüls (1995)	0	0	0	1	1	2	2	6	Low
f) Densely sintered alumina									
Vanoorbeek et al. (2010)	0	3	2	2	3	1	1	12	Moderate
Kokubo et al. (2009)	0	3	2	3	3	2	2	15	High
Walter el al. (2005)	0	3	1	1	1	3	3	12	Moderate
Ödmann & Andersson (2001)	0	2	3	3	3	3	3	17	High
Oden et al. (1998)	0	3	1	2	1	3	3	13	Moderate
g) Densely sintered zirconia (veneered)									
Prause et al. (2022)	0	2	1	3	1	3	2	12	Moderate
Torres et al. (2021)	3	3	2	3	2	2	1	16	High
Serra-Pastor et al. (2021)	0	3	2	1	1	3	2	12	Moderate
Seidel et al. (2020b)	0	3	2	2	1	1	3	12	Moderate
Cagidiaco et al. (2019)	0	3	2	1	1	3	3	13	Moderate
Cantner et al. (2019)	0	3	2	1	1	2	0	9	Moderate
Lundgren et al. (2018b)	0	2	2	2	1	3	3	13	Moderate

Appendix Table 8 Quality-Assessment-Scale for Reconstructive Studies (QAS-RS) of the Included Studies *(cont)*

	Sample			Outcomes					
Reference	Sample size determination	Reporting of follow-up frequency	Inclusion and exclusion criteria	Outcome assessment	Reporting of failures and complications	Follow-up duration	Dropout rate during follow-up	Total (maximum 21)	Overall quality assessment
Dogan et al. (2017)	0	3	2	3	3	2	3	16	High
Monaco et al. (2017b)	1	3	2	3	3	2	3	17	High
Güncü et al. (2016)	2	3	2	2	3	2	3	17	High
Ferrari et al. (2015)	0	3	2	3	1	2	3	14	Moderate
Rinke et al. (2013b)	0	3	2	1	2	2	3	13	Moderate
Sagirkaya et al. (2012)	0	3	2	2	1	2	3	13	Moderate
Vigolo & Mutinelli (2012b)	0	3	1	3	1	2	3	13	Moderate
Vigolo & Mutinelli (2012c)	0	3	1	3	1	2	3	13	Moderate
Beuer et al. (2010)	0	3	2	1	2	1	3	12	Moderate
Schmitt et al. (2010)	0	3	0	2	1	2	2	10	Moderate
h) Densely sintered zirconia (monolithic & microveneered)									
Gseibat et al. (2023)	1	3	2	3	3	2	3	17	High
Barile et al. (2023)	0	3	2	2	1	3	3	14	Moderate
Waldecker et al. (2022a)	0	3	3	1	2	3	3	15	High
Waldecker et al. (2022b)	0	3	3	1	2	3	3	15	High
Le et al. (2022b)	0	3	2	3	2	2	3	15	High
Le et al. (2022c)	0	3	2	3	2	2	3	15	High
Hammoudi et al. (2022b)	0	2	2	3	2	1	3	13	Moderate
Kasem et al. (2022b)	0	3	2	3	3	2	3	16	High
Gardell et al. (2021b)	1	3	2	3	2	2	3	16	High
Solá-Ruíz et al. (2021)	1	3	2	1	3	3	3	16	High
i) Zirconium silicate ($ZrSiO_4$)									
Passia et al. (2013)	0	3	2	1	1	2	1	10	Moderate