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Review article

Clinical outcomes and complications of tooth- and implant-supported lithium (di)silicate based single crowns: an overview of systematic reviews

Harald Laumbacher [a], Konstantin J Scholz [a,b], Helge Knüttel [c], Martin Rosentritt [d,*]

[a] Department of Conservative Dentistry and Periodontology, UKR University Hospital Regensburg, 93042 Regensburg, Germany
[b] Department of Operative Dentistry and Periodontology, Center for Dental Medicine, Medical Center- University of Freiburg, Faculty of Medicine, University of Freiburg, 79106 Freiburg, Germany
[c] University Library, University of Regensburg, 93042 Regensburg, Germany
[d] Department of Prosthetic Dentistry, UKR University Hospital Regensburg, 93042 Regensburg, Germany

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ABSTRACT

Objectives: To critically synthesize and evaluate the clinical outcomes, complications, material-specific performance, and methodological quality associated with lithium (di)silicate-based single crowns, in light of current systematic reviews.

Data/Sources: MEDLINE via Ovid, Embase via Ovid, Trip Pro Medical Database, Epistemonikos Database and Cochrane Database of Systematic Reviews (via Cochrane Library/Wiley) without restriction of date of publication or language. Reviews reported on the clinical survival, technical and biological complications, antagonist wear, and fabrication techniques of tooth- and implant-supported lithium (di)silicate single crowns were included. Methodological quality was assessed using the AMSTAR 2 tool.

Study selection: The systematic search updated in February 2025 identified 1760 records from electronic databases. Ultimately, 28 systematic reviews on approximately 35,000 crowns published between 2007 and 2024 were included in the qualitative analysis. Lithium (di)silicate crowns demonstrated excellent short- and medium-term survival rates (95–100 %) in the range of metal-ceramic crowns. Antagonist enamel wear was minimal and similar to that of natural teeth when polished surfaces were ensured. However, substantial methodological heterogeneity, limited long-term data (>5 years), and a concentration of studies on a single product (IPS e.max) were noted, limiting the generalizability of findings. The frequent pooling of diverse materials and restoration types without appropriate subgroup analyses further compromised the reliability of meta-analytic conclusions.

Conclusions: Lithium (di)silicate crowns show excellent clinical performance in the short- and medium-term. Nevertheless, careful interpretation is warranted due to methodological variability, material-specific differences, and insufficient long-term data for newer lithium (di)silicate systems. Future research should address these gaps through standardized outcome reporting, material-specific studies, and investigation of broader biological effects.

Clinical Relevance: Lithium (di)silicate ceramics provide an aesthetically and mechanically reliable option for single crowns in both anterior and posterior regions. Clinical evidence supports their excellent short- and medium-term survival with minimal antagonist wear, particularly when proper surface finishing protocols are followed. However, clinicians should be aware of material-specific differences among commercially available lithium (di)silicate systems and be cautious when extrapolating clinical results obtained from specific products to others. In light of limited long-term clinical data, practitioners should communicate both the well-documented short- to medium-term benefits and the remaining uncertainties regarding long-term performance. This overview also emphasizes the importance of critical appraisal of systematic reviews and encourages careful interpretation of pooled results, particularly in the presence of high heterogeneity or inappropriate data aggregation.

* Corresponding author at: Department of Prosthetic Dentistry, UKR University Hospital Regensburg, 93042 Regensburg, Germany.
E-mail address: martin.rosentritt@ukr.de (M. Rosentritt).

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1. Introduction

The first glass ceramic material with lithium (di)silicate ($LiSi_{(2)}$) as the main component of the crystalline phase was introduced to the market in 1998, marking a significant milestone in restorative dentistry. Initially marketed as a pressable ceramic, $LiSi_{(2)}$ rapidly gained popularity due to its superior combination of mechanical strength and optical translucency, compared to previous feldspathic or leucite-reinforced glass ceramics [1]. In 2005, modified versions with improved mechanical and optical properties were introduced. In addition to an enhanced pressable ceramic, a CAD/CAM-compatible version was developed. This material undergoes a two-step crystallization process, involving initial machining in the softer lithium metasilicate ($Li_{(2)}SiO_{(3)}$) stage, followed by a second heating step to transform into the more durable lithium (di) silicate ($Li_{(2)}Si_{(2)}O_{(5)}$) crystallites. The machinable CAD/CAM version facilitates efficient chairside processing and occlusal adjustment and has thus contributed significantly to the widespread clinical acceptance of these materials [2–4].

In 2013, a further modification occurred with the development of lithium silicate glass-ceramics containing approximately 10 % zirconium dioxide ($ZrO_{(2)}$) [5,6]. The addition of zirconia particles circumvented previous patent requirements and aimed to enhance the material's mechanical strength by stopping crack propagation and improving fracture toughness [7]. This composition is intended to combine the positive mechanical properties of zirconium oxide with glass-ceramic aesthetics [8–10]. Further $LiSi_{(2)}$ variations are co-crystallized ceramics such as lithium aluminosilicate ($LiAlSi_{(2)}O_{(6)}$), designed to further tailor mechanical properties and broaden clinical applicability [11] as these ceramics do not require additional crystallization after milling. Current lithium-silica dental glass-ceramics provide different glass composition and crystallite fraction. The glass composition is strongly influenced by varying SiO_2:Li_2O ratios. The crystalline fraction varies between micrometric and nanometric crystals or a mixture of sub-micrometric and nano-metric particles [12].

The broad adoption of $LiSi_{(2)}$ ceramics is evident from a survey conducted among 1000 dentists in Germany, revealing that $LiSi_{(2)}$ accounted for approximately 20 % of all indirect restorative materials used in 2017, with an expected continued increase in usage. $LiSi_{(2)}$ has thereby largely replaced other glass ceramics due to its higher strength and extended range of indications [13].

Clinical evidence supports the long-term durability of $LiSi_{(2)}$, highlighted by a comprehensive longitudinal study spanning 16.9 years on 2392 restorations made of IPS e.max Press, where no additional failures were reported after eight years in clinical service [14]. During this long-term use under functional conditions in the oral cavity, both the restorations and their antagonists are constantly exposed to tribological, thermical and chemical stress. Clinical failures most commonly include fracture, chipping, abrasion, discoloration, and biological failures such as secondary caries, with fractures being the predominant issue reported [15].

The interaction between $LiSi_{(2)}$ restorations and the natural dentition raises questions regarding potential adverse effects over time, particularly focusing on wear interactions between the ceramic material and less abrasion- and attrition-resistant natural teeth, possibly even leading to changes in the masticatory system on the anatomical and functional level [16,17]. As $LiSi_{(2)}$ restorations have been on the market for almost 30 years, their clinical success and complications should be well and widely documented in all aspects.

2. Review objectives

This overview aims to provide a consolidated and critically appraised summary of the current evidence from systematic reviews (SR) on the clinical outcome and complications of tooth- or implant supported $LiSi_{(2)}$ single crown (SC) restorations and discuss whether the conceivable range of possible complications and effects on the stomatognathic system is documented in the literature.

Specifically, this article will help readers to:

(1) Understand the overall survival and success rates reported across multiple SRs.
(2) Identify common types of complications associated with $LiSi_{(2)}$ SCs.
(3) Appreciate the methodological strengths and weaknesses of the existing SRs in this field, which is crucial for interpreting their validity.
(4) Identify persistent evidence gaps that require further primary research or new, targeted SRs.

3. Methods

The overview was conducted and reported in accordance with the Preferred Reporting Items for Overviews of Systematic Reviews including harms (PRIO-harms) checklist [18]. The protocol was developed according to the PRISMA-P reporting guideline [19] and was published prospectively [20]. A detailed PRIO-harms compliance table with item-specific justifications and corresponding manuscript locations is provided in the supplementary Appendix 1.

3.1. Eligibility criteria

SRs that reported on clinical outcomes and complications of tooth- or implant-supported $LiSi_{(2)}$-based SCs in adult humans were included. To ensure high sensitivity, no additional restrictions were applied. The PICOS criteria were defined as depicted in Table 1. In cases where updated reviews were conducted at different points in time, only the most recent publication was included. When publications were available in multiple languages, only the English version was considered.

3.2. Search strategy

Literature search was conducted in MEDLINE via Ovid, Embase via Ovid, Trip Pro Medical Database, Epistemonikos Database and Cochrane Database of Systematic Reviews (via Cochrane Library/Wiley), without restriction of date of publication or language. An initial search strategy aiming at high sensitivity was developed for MEDLINE using text words and MeSH subject headings. Once finalized this strategy was adapted to the syntax and controlled vocabulary of the other databases. We are not aware of recent comparative evaluations of search filters for systematic reviews. Therefore, for MEDLINE and Embase we used the sensitive filter of Canada's Agency for Drugs and Technologies in Health (CADTH) [21]. This strategy builds upon those by Poggio et al. and Laumbacher et al. [22,23]. The searches were run in all databases in February 2023 and were updated by rerunning the strategies in MEDLINE and Embase (last search in February 2025). Full search strategies for all databases, along with PRISMA-S [24] and TARCiS [25] checklists, are available in the supporting data [26]. The electronic searches were complemented by reference list checking of all included reviews for additional relevant articles, forward citation searching using PubMed functions "Cited by" and snowballing with the PubMed function "Similar articles" [27,28]. Results were transferred to Citavi (version 6, Swiss Academic Software GmbH, Wädenswil, Switzerland) and duplicates removed with the inbuilt mechanism.

Table 1
PICOS framework.

P (Population)	Adults who received single crown restorations
I (Intervention)	$LiSi_{(2)}$ based single crown restorations
C (Comparison)	Other types of restorative material or no comparison
O (Outcome)	Clinical survival and/or technical, biological or aesthetic complications
S (Studies)	Systematic reviews on in vivo studies with a follow-up

Records were screened in a first round by titles and abstracts followed by a second round of study selection based on the full text. In each round, selection was done by two authors independently (HL, KS) and blinded using the collaboration tool Rayyan [29]. Conflicting votes found after unblinding were resolved by discussion. Full texts, which did not meet the eligibility criteria were excluded. The process for selecting studies was outlined in a PRISMA flow diagram (Fig. 1) [30].

3.3. Outcomes

Outcomes, which are considered, are clinical survival rate and incidence of technical, aesthetical and/or biological complications. Survival is defined as the restoration being clinically acceptable in situ for the follow-up time without refabrication. Complication is defined as one or more events affecting function and/or aesthetics negatively and/or resulting in biological pathologies [31].

3.4. Methodological quality

To assess the methodological quality and risk of bias of included systematic reviews, the AMSTAR 2 critical appraisal tool for systematic reviews was used [32].

3.5. Data collection process and data items

Data was collected using Excel spreadsheets (Microsoft). The following information was extracted from systematic reviews: first author, year of publication, title, PMID, DOI, objective, included studies, types of studies, period of studies, type of restoration, region of restoration (anterior/posterior), reporting items, materials, number of patients, number of restorations, follow up time, survival, technical complications, biological complications and aesthetic complications. Complications were noted solely for $LiSi_{(2)}$ restorations if possible. All primary studies on $LiSi_{(2)}$ included in the systematic reviews were retrieved, if possible, and the following information extracted: first author, year of publication, reference, timeframe of recruitment, study design, setting, type of restoration (single crown, implant crown), region of restoration (anterior/posterior), pulp vitality, material, chairside or laboratory-based fabrication, veneered or monolithic restorations, luting procedure, luting material, surface treatment (polished or glazed), number of patients and number of restorations at baseline and last follow-up, mean age, follow-up, evaluation criteria, outcome, conflicts of interest and funding. When different numbers of patients or restorations at baseline and follow-up were provided, numbers at latest follow-up were chosen for analysis. Data extraction was done by one author (HL) and overseen by two additional reviewers (KS, MR).

3.6. Data analysis

We provided matrix of evidence tables, listing the references included in each of the systematic reviews, and assessed the extent of primary study overlap. Data was grouped according to type of restoration and material. It was not statistically analyzed because of heterogeneity.

The degree of overlap between included primary studies was assessed and visualized with the Graphical Representation of Overlap for

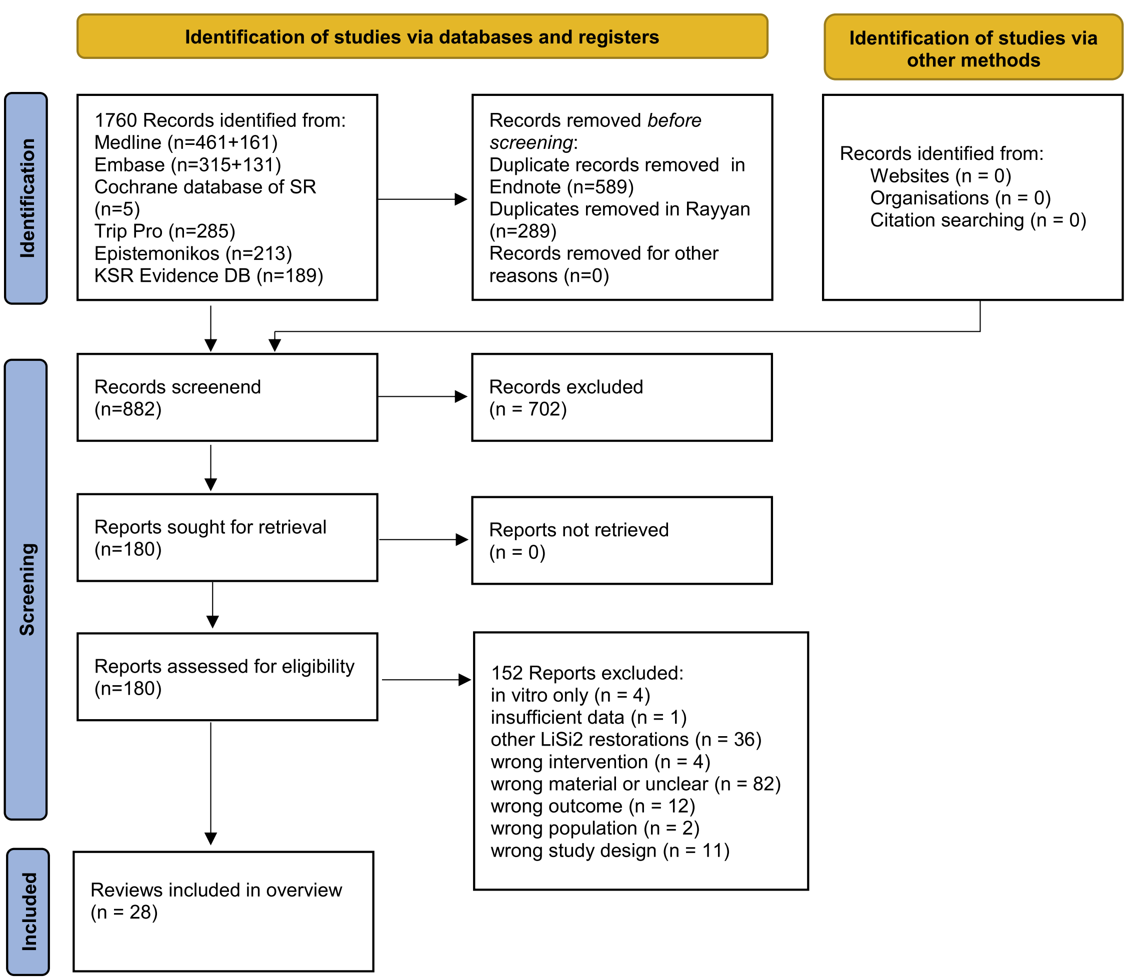

Fig. 1. PRISMA 2020 flow diagram [30].

Overviews (GROOVE) tool [33].

The certainty of evidence was assessed using the GRADE approach, following current guidance for overviews of systematic reviews and guideline development [34–36]. For each outcome, five domains - risk of bias, inconsistency, indirectness, imprecision, and publication bias - were evaluated based on the methodological quality and reporting of the included systematic reviews.

3.7. Protocol deviations

The original protocol aimed to provide a comprehensive overview of systematic reviews addressing all types of lithium disilicate-based restorations, including crowns, veneers, inlays/onlays, and fixed dental prostheses. The initial literature search yielded 64 eligible systematic reviews. However, due to the high number and substantial heterogeneity in restoration types, clinical indications, and outcome measures, the authors decided to limit the scope of this overview to systematic reviews focusing exclusively on $LiSi_{(2)}$ SCs on teeth and implants. This decision was made to ensure methodological clarity and comparability of findings, and to allow for a more focused synthesis of the clinical evidence. As a result, 36 systematic reviews addressing other types of $LiSi_{(2)}$ restorations were excluded from the final analysis (see Appendix 3). In addition to the published protocol, the certainty of evidence across the key clinical outcomes was assessed using the GRADE approach, and the reporting quality was appraised using the PRIO-harms checklist.

Furthermore, the original title of this overview, as registered in the published protocol, was "Long-term clinical outcomes and complications of tooth- and implant-supported lithium (di)silicate-based single crowns: an overview of systematic reviews." Following a reviewer's comment during peer review, highlighting that most included studies report short- to medium-term follow-up periods, the title was revised to "Clinical outcomes and complications…" to more accurately reflect the scope and limitations of the available evidence. This change aims to prevent misinterpretation regarding the temporal extent of the findings.

4. Results

The systematic search conducted in February 2023, and updated in February 2025, identified 1760 records from electronic databases. Despite comprehensive searches of bibliographies and forward snowballing, no additional eligible articles were found. As all relevant articles from the initial search were retrieved via MEDLINE and Embase, the subsequent update focused exclusively on these two databases. For 180 reviews appearing to meet inclusion criteria or lacking sufficient abstract information, full-text articles were assessed. A total of 152 articles were excluded with reasons specified (Appendix 3). Ultimately, 28 systematic reviews published between 2007 and 2024 were included in the qualitative analysis (Fig. 1). Of these, 22 addressed TS SC (tooth-supported single crown) restorations, five focused exclusively on IS SC (implant-supported single crown) restorations, and one addressed both. A complete list of all included systematic reviews is presented in Table 2, with detailed information available in Appendix 4.

The included reviews were based on 65 primary in vivo $LiSi_{(2)}$ studies, reporting on approximately 35,000 $LiSi_{(2)}$ SCs. A total of 37 studies investigated TS SCs, 25 focused on IS SCs and 3 covered both. Seven studies were follow-ups of previously published investigations [37–43]. Potential cohort overlap was identified in two retrospective studies sharing identical settings and ethical approvals [44,45]. When such overlap was detected, only the most recent data set was used. Fifteen randomized controlled trials were identified, involving 863 crowns with follow-up periods ranging from 0.5 to 6.7 years (mean: 2.7 $\pm$ 1.6 years). Twenty-five prospective non-RCT studies encompassed 3544 crowns, with follow-up periods between 0.5 to 11.4 years for TS SCs and up to 13.3 years for IS SCs (mean: 3.4 $\pm$ 2.9). Additionally, 17 retrospective studies covered 30,797 crowns, with follow-ups from 1.7 to 6.1 years (mean: 3.5 $\pm$ 1.3). Three retrospective studies based on warranty claims accounted for 28,046 TS restorations (9053 IPS e.max CAD SCs and 3095 IPS e.max CAD on zirconia SCs [46], 15,765 IPS e.max SCs [47], and 93 Empress 2 SCs [48]) sourced from commercial dental laboratories, without patient examination. When including laboratory data, approximately 95 % of all reported restorations were IPS e.max or Empress 2; without laboratory data, approximately 75 % (Fig. 2a,b).

Individual studies were cited in a range of 1 to 9 reviews (mean: 2.4) and each review included between 1 and 19 studies on $LiSi_{(2)}$ SCs (mean: 5.7). The overlap of primary studies in this overview was high for SRs on TS SCs (0–66,7 %; Corrected Covered Area (CCA): 12.40 %, Fig. 3a) and IS SCs (0–33,3 %; CCA: 12.20 %, Fig. 3b). Substantial variability was noted in the criteria used to evaluate clinical outcomes. Specifically, 19 reviews applied (modified) USPHS criteria, 10 used (modified) CDA criteria, and only 2 employed the more detailed FDI evaluation system. Four reviews referred to other criteria, while 20 did not provide any information on the evaluation standards used. A full list of studies can be found in Appendix 5.

4.1. Survival and success

4.1.1. Tooth-supported single crowns (TS SCs)

Survival rates for TS SCs have been documented in 30 primary studies. Short-term survival (<3 years) ranged from 95.5 % [49] to 100 % [50–55], medium-term (3–5 years) from 93.8 % [56] to 100 % [56–60], and long-term (>5 years) from 83.5 % [39] to 100 % [61]. Mazza et al. [62] reported a pooled survival for $LiSi_{(2)}$ of 99 % (CI 94–100 %). However, the period to which this related was not specified, and studies with markedly divergent follow-ups between 24 and 167 months were included. The analysis revealed substantial heterogeneity, as evidenced by $I^2 = 77$ %, $\tau^2 = 2.5437$, $P = .01$. Pieger et al. [63] conducted a life table analysis and calculated cumulative survival rates of 100 % at two years, 97.9 % at five years, and 96.7 % at eleven years. However, survival rates beyond four years were based on only one retrospective study [64]. Sailer [65] reported five-year survival for leucite and $LiSi_{(2)}$-reinforced glass-ceramic crowns at 96.6 % (CI 94.9–97.7), but not for $LiSi_{(2)}$ separately, and did not report on heterogeneity. The survival rate of reinforced glass-ceramic crowns was found to be in a similar range as metal-ceramic (95.7 %) and glass-infiltrated ceramic crowns (94.6 %), as well as densely sintered alumina (96.0 %). However, it was significantly higher than that of feldspathic or silica-based ceramics (90.7 %). In a 2016 corrigendum [66], a study in the zirconia group was subsequently excluded from the meta-analysis, because it did not include densely sintered zirconia crowns but rather crowns made from $ZrSiO_{(4)}$, which have a lower flexural strength. This exclusion resulted in an enhancement in the 5-year survival rate, elevating it from 91.2 % to 93.8 %. Consequently, the survival rate was no longer significantly lower than that of $LiSi_{(2)}$ or metal-ceramics. Except for ceramics derived from feldspar or silica, there was no substantial variance in survival outcomes based on the location of the crown.

Twelve studies reported success rates ranging from 96.6 % [67] to 100 % [50,51,54] for short-term investigations, from 89.7 % [59] to 100 % [60] for medium-term investigations, and from 71.0 % [39] to 86.4 % [45] for long-term investigations.

4.1.2. Implant-supported single crowns (IS SCs)

Survival rates for IS SCs were reported in twelve studies. Short-term survival was 100 % [68–73], medium-term ranged from 79.7 % [74] and 100 % [57,75–78] and long-term survival was reported at 93.8 % in one study [79].

Spitznagel et al. [80] calculated survival rates of 99 % at one and two years and 100 % at five years, with the five-year data derived from two studies encompassing a total of 36 restorations [40,75]. Pjetursson et al. [81] estimated survival rates after three years for veneered reinforced glass-ceramic crowns at 97.6 % and for monolithic-reinforced

Table 2
Included Systematic Reviews (see Appendix 4 for detailed information).

Author	Titel	Included studies ($LiSi_{(2)}$ SC)	Materials (Number of studies)	(Core) Ceramic material details ($LiSi_{(2)}$)	Number of $LiSi_{(2)}$ Restorations	Follow up time (y)	Survival (meta-analysis - %)
Al-Dulaijan, 2023 [109]	Clinical outcomes of single full-coverage lithium disilicate restorations: A systematic review	19 (19)	$LiSi_{(2)}$ (19) Zir (2) MC (1)	NR	2134	0.5–9	NR
Al-Haj Husain, 2020 [91]	Clinical Performance of Partial and Full-Coverage Fixed Dental Restorations Fabricated from Hybrid Polymer and Ceramic CAD/CAM Materials: A Systematic Review and Meta-Analysis.	28 (8)	$LiSi_{(2)}$ (8) Zir (1) AC (4) GC (10) MC (1) Other (6)	IPS e.max CAD (2) IPS e.max press (3) IPS Empress II (2) NR (4)	SC 381	2–10	no meta-analysis for $LiSi_{(2)}$ (82.8–100)
Aldegheishem, 2017 [110]	Success and Survival of Various Types of All-Ceramic Single Crowns: A Critical Review and Analysis of Studies with a Mean Follow-Up of 5 Years or Longer.	14 (1)	$LiSi_{(2)}$ (1) Al_2O_3 (8) Zir (2) GC (4)	IPS e.max press	94	2.8–9.1	Only 1 $LiSi_{(2)}$ study in meta-analysis: 97.6 (5y) (Gehrt 2013)
AlMashaan & Aldakheel, 2023 [97]	Survival of Complete Coverage Tooth-Retained Fixed Lithium Disilicate Prostheses: A Systematic Review	25 (25)	$LiSi_{(2)}$ (25) Zir (2) MC (3) Other (1)	NR	6114	2–16.9	NR
Araujo, 2016 [98]	Survival of all-ceramic restorations after a minimum follow-up of five years: A systematic review.	29 (8)	$LiSi_{(2)}$ (8) Zir (7) Al_2O_3 (5) GC (9)	IPS e.max press (4) Empress II (5)	SC 200 FPD 88 I/O 40 V 300	5–10	Survival rate not calculated in meta-analysis, data from primary studies for SC: 94.8–100
Aswal, 2023 [85]	Clinical Outcomes of CAD/CAM (Lithium disilicate and Zirconia) Based and Conventional Full Crowns and Fixed Partial Dentures: A Systematic Review and Meta-Analysis	13 (4)	$LiSi_{(2)}$ (4) Zir (2)	NR	294	1–2	Survival rate for $LiSi_{(2)}$ not calculated in meta-analysis, data from primary studies for SC: 95.5–100
Aziz, 2020 [90]	Clinical outcomes of lithium disilicate glass-ceramic crowns fabricated with CAD/CAM technology: A systematic review	6	$LiSi_{(2)}$ (7)	IPS e.max CAD	204	2–10	NR
Benli, 2022 [93]	Clinical performance of lithium disilicate and zirconia CAD/CAM crowns using digital impressions: A systematic review	6 (6)	$LiSi_{(2)}$ (6) Zir (4)	NR	12,290	0.5–3.5	NR
Conrad, 2007 [111]	Current ceramic materials and systems with clinical recommendations: a systematic review.	23 (3)	$LiSi_{(2)}$ (3) GC (6) Al_2O_3 (10) $MgAl_2O_4$ (2) Zir (3) MC (1)	IPS e.max press (1) Empress II (2)	SC 27 FPD 97 IRFPD 45	1–5.1	NR
Ferrairo, 2024 [100]	Biomechanical consideration in tooth-supported glass-ceramic restorations: A systematic review and meta-analysis of survival rates and irreparable failures	46 (9)	$LiSi_{(2)}$ (9) GC (3)	NR	SC 671	2–10	no meta-analysis for $LiSi_{(2)}$ alone (79.2–100)
Flores-Ferreyra, 2024 [89]	Dental human enamel wear caused by ceramic antagonists: A systematic review and network meta-analysis.	10 (3)	$LiSi_{(2)}$ (3) Zir (9) MC (4)	NR	NR	1–3	NR
Hmaidouch, 2013 [88]	Tooth wear against ceramic crowns in posterior region: a systematic literature review.	3 (3)	$LiSi_{(2)}$ (3) MC (2) Al_2O_3 (1)	IPS e.max press (3) Empress II (1)	84	0.5–3	NR
Kassardjian, 2016 [99]	A systematic review and meta analysis of the longevity of anterior and posterior all-ceramic crowns.	14 (2)	$LiSi_{(2)}$ (2) Al_2O_3 (10) Leucite (1) Zir (1)	Empress II (1) IPS e-max (1)	173	5–8	NR for $LiSi_{(2)}$ seperately
Lemos, 2024 [82]	Survival and prosthetic complications of monolithic ceramic implant-supported single crowns and fixed partial dentures: A systematic review with meta-analysis.	28 (11)	$LiSi_{(2)}$ (11) Zir (16) Leucite (1) MC (2)	IPS e.max CAD (3) IPS e.max press (4) IPS e.max (3) LiSi(2) (1)	572	1–6.7	98 (95–100)
Mao, 2024 [86]	Antagonist enamel tooth wear produced by different dental ceramic systems: A systematic review and network meta-analysis of controlled clinical trials.	7 (1)	$LiSi_{(2)}$ (1) Zir (7) MC (2)	NR	15	1	NR
Maroulakos, 2019 [101]	Effect of cement type on the clinical performance and complications of zirconia and lithium disilicate tooth-supported crowns: A systematic review.	17 (11)	$LiSi_{(2)}$ (11) Zir (7)	e.max CAD (2) e.max Press (5) Empress II	2120	2.1–10.1	Survival rate not calculated in meta-analysis, data from primary studies: 83.5–100

(continued on next page)

Table 2 (*continued*)

Author	Titel	Included studies (LiSi$_{(2)}$ SC)	Materials (Number of studies)	(Core) Ceramic material details (LiSi$_{(2)}$)	Number of LiSi$_{(2)}$ Restorations	Follow up time (y)	Survival (meta-analysis - %)
				(3) e.max (2) NR (1)			
Mazza, 2021 [62]	Survival and complications of monolithic ceramic for tooth-supported fixed dental prostheses: A systematic review and meta-analysis.	19 (7)	LiSi$_{(2)}$ (7) Zir (9) PICN (1)	e.max CAD (4) e.max Press (3) Empress II (1)	SC 524 FPD 36	SC 2–3 FPD 13.9	LiSi$_{(2)}$ SC: 99 (94–100) Zir SC: 99 (96–100) PICN SC: 93 (85–97)
Pieger, 2014 [63]	Clinical outcomes of lithium disilicate single crowns and partial fixed dental prostheses: a systematic review.	12 (12)	LiSi$_{(2)}$ (12)	IPS e.max CAD (3) IPS e.max press (5) IPS Empress II (4) NR (1)	849	0.5–11.1	Life table analysis: cumulative survival rate SC: 2y 100 %, 5y 97.86 %, 11y 96.74 % FPD: 2y 83.39, 5y 78.11, 11y 70.93
Pjetursson, 2021 [81]	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.	49 (13)	LiSi$_{(2)}$ (12) Zir (31) Other (6) Al_2O_3 (4) RNC (2)	IPS e.max press IPS e.max CAD	451 (drop out 19)	1.0–11.9 (mean)	Estimated 3y: 97.0 % monolithic 97.6 % veneered
Rabel, 2018 [83]	The clinical performance of all-ceramic implant-supported single crowns: A systematic review and meta-analysis	41(8)	LiSi$_{(2)}$ (8) Zir (18) Al_2O_3 (5) Other (13)	IPS e.max CAD (3) IPS e.max press (2) IPS e.max (2) LiSi(2) (1)	334	1–4.6	For all materials: 91.0 (51.3–98.7)
Rodrigues, 2019 [92]	CAD/CAM or conventional ceramic materials restorations longevity: a systematic review and meta-analysis	14(2)	LiSi$_{(2)}$(2) Zir (9) MC (7) GC (4) other (1)	NR	30	SC: 2 (mean) PC: 7 (mean)	NR for LiSi$_{(2)}$ seperately
Sailer, 2015 [65, 66]	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).	67 (5)	LiSi$_{(2)}$ (5) Zir Leucite MC	NR	1033	3.2–6.6	Leucite and lithium-disilicate reinforced glass ceramics pooled: 96.6 (94.9–97.7)
de Souza Melo, 2018 [112]	Association of sleep bruxism with ceramic restoration failure: A systematic review and meta-analysis.	8 (3)	LiSi$_{(2)}$ (3) GC (2) Zir (1) Feldspathic (2) Leucite (2)	NR	NR	1–20	NR for LiSi$_{(2)}$ seperately
Spitznagel, 2017 [113]	Prosthetic protocols in implant-based oral rehabilitations: A systematic review on the clinical outcome of monolithic all-ceramic single- and multi-unit prostheses	3 (2)	LiSi$_{(2)}$ (2) Zir (1)	IPS e.max CAD (1) IPS e.max press (1)	69	mean 2.4–2.6	NR
Spitznagel, 2022 [80]	Clinical outcomes of all-ceramic single crowns and fixed dental prostheses supported by ceramic implants: A systematic review and meta-analyses.	8 (5)	LiSi$_{(2)}$ (5) Zir (5)	IPS e.max CAD (2) IPS e.max press (1) IPS e.max (2)	180	1–3	1y 99 % (95–100) 2y 99 % (95–100) 5y 100 % (95–100)
Vagropoulou, 2018 [114]	Complications and survival rates of inlays and onlays vs complete coverage restorations: A systematic review and analysis of studies	9 (3)	LiSi$_{(2)}$ (3) Silicate ceramic (1) Feldspathic (3) Leucite (4) Cast gold (2) MC (1)	NR	16,286 SC 1155 I/O	NR	not calculated for LiSi$_{(2)}$ seperately
Velastegui, 2022 [87]	Enamel Wear of Antagonist Tooth Caused by Dental Ceramics: Systematic Review and Meta-Analysis	14 (3)	LiSi$_{(2)}$ (3) ZLS (1) Other (14)	IPS e.max CAD (1) IPS e.max Press (2) Empress II (1) Suprinity (1)	NR	0.5–5.2	NR
Wang, 2012 [115]	A systematic review of all-ceramic crowns: clinical fracture rates in relation to restored tooth type.	37 (4)	LiSi$_{(2)}$ (4) Other (33)	IPS e.max press (1) Empress II (3)	397	3–5	NR

AC – alumina-reinforced ceramic; Al_2O_3 – aluminum oxide ceramic; CAD/CAM – computer-aided design / computer-aided manufacturing; FPD – fixed dental prosthesis; GC – glass ceramic; I/O – inlay/onlay; IRFPD – inlay-retained fixed partial denture; LiSi$_{(2)}$ – lithium (di)silicate; MC – metal ceramic; $MgAl_2O_4$ – magnesium aluminum spinel; NR – not reported; Other – other materials not further specified; PC – partial coverage; PICN – polymer-infiltrated ceramic network; RNC – resin nanoceramic; SC – single crown; TS – tooth-supported; IS – implant-supported; V – veneer; Zir – zirconia; ZLS – zirconia-reinforced lithium silicate.

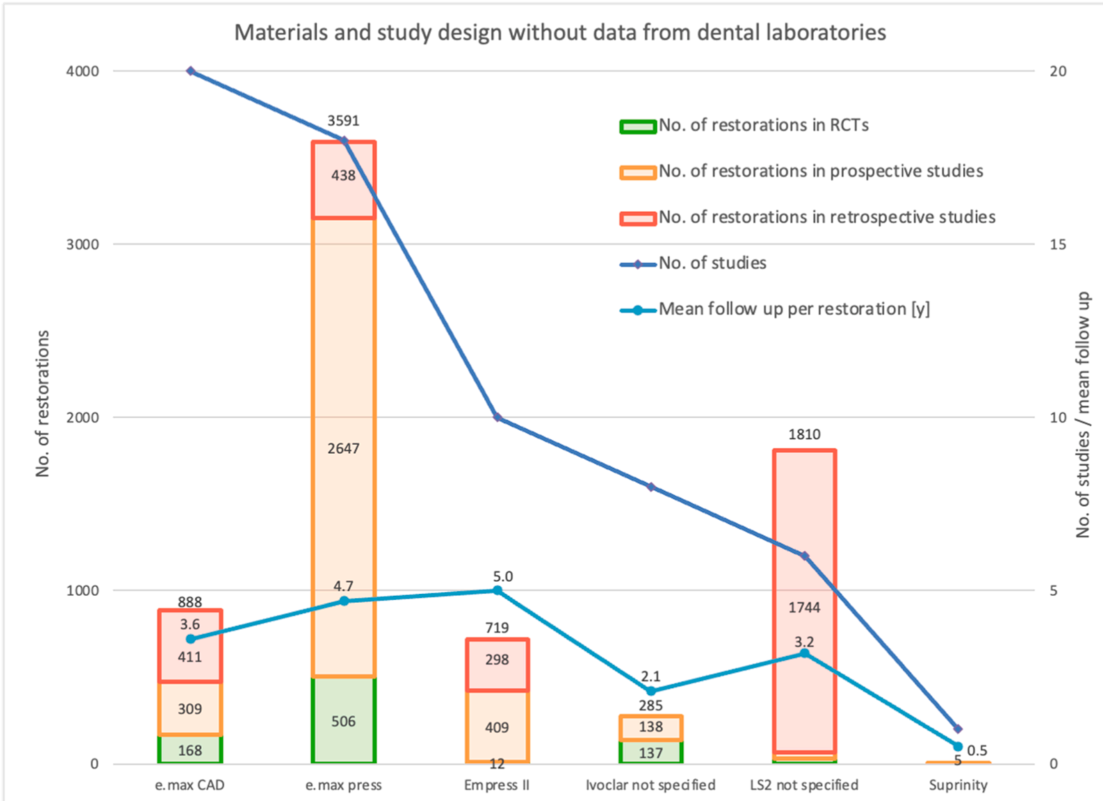

Fig. 2a. Materials and study design without data from dental laboratories.

glass-ceramic crowns at 97.0 %, but combined $LiSi_{(2)}$, leucite, and fluorapatite ceramics in these groups. Lemos et al. [82] reported survival rates at 98 % (95 %-CI: 95–100 %) for $LiSi_{(2)}$ IS SCs characterized by substantial heterogeneity (I^2=71 %, τ^2=0.0137, P<.01) and without providing a time frame. Rabel et al. [83] indicated survival of monolithic $LiSi_{(2)}$ crowns at 91 % (95 %-CI: 51.3–98.7 %).

Seven studies reported success varying between 97.5 % [68] and 100 % [69–71] for short-term investigations and between 89 % [78] and 100 % [76] for medium-term investigations. No long-term success data were available.

4.2. Technical complications

The most prevalent technical complications in TS SCs were fractures, including chipping and catastrophic failures, as well as loss of retention. Marginal discrepancies, deficient proximal contact point, post fracture and anatomic form were also noted in certain reviews (Table 3).

IS SCs showed similar trends with additional occurrences of abutment or screw loosening. Higher fracture rates for screw-retained crowns were attributed to weakening of the ceramic due to the screw channel [83,84]. Lemos et al. [82] observed no significant difference between monolithic zirconia and $LiSi_{(2)}$ regarding complications and survival. Pjetursson et al. [81] reported significantly higher annual core fracture rates for monolithic reinforced glass-ceramics (0.25 %) compared to monolithic zirconia (0 %), but significantly lower rates for abutment fractures (0 % vs. 0.39 %), screw loosening (0.1 % vs. 2.27 %) and loss of retention (0.25 % vs. 4.55 %). Differences between veneered and monolithic reinforced glass-ceramics were clinically irrelevant in this meta-analysis, while veneered $LiSi_{(2)}$ crowns showed approximately twice the chipping rate compared to monolithic designs in two clinical studies [73,78].

4.3. Biological complications

The most prevalent biological complications in TS SCs included endodontic issues, secondary caries and tooth fracture, followed by periodontal problems and postoperative hypersensitivity.

In IS SCs, peri-implantitis and soft tissue complications were most frequent. The lowest annual soft tissue complications were associated with monolithic reinforced glass-ceramics (1.1 %), followed by veneered reinforced glass-ceramics (1.57 %), veneered zirconia (2.73 %), and monolithic zirconia (3.9 %) [81].

4.4. Aesthetic performance

Both tooth- and implant-supported $LiSi_{(2)}$ crowns demonstrated excellent aesthetic outcomes, particularly in the anterior region. Marginal discoloration was the only notable aesthetic complication [85].

4.5. Tooth wear

Four systematic reviews compared wear of teeth and restorations by different materials. Overall, $LiSi_{(2)}$ crowns caused minimal antagonist enamel wear, comparable to that of natural enamel. Mao et al. [86] reported a not significant mean vertical loss difference of 5 μm (95 % CI: −48.2 to 58.1 μm) compared to natural teeth. Similarly, Velastegui et al. [87] found that $LiSi_{(2)}$ caused very low linear and volumetric enamel wear, second only to polished zirconia. Hmaidouch and Weigl [88] also observed that $LiSi_{(2)}$ crowns resulted in less or comparable antagonist wear relative to traditional metal-ceramic restorations and emphasized

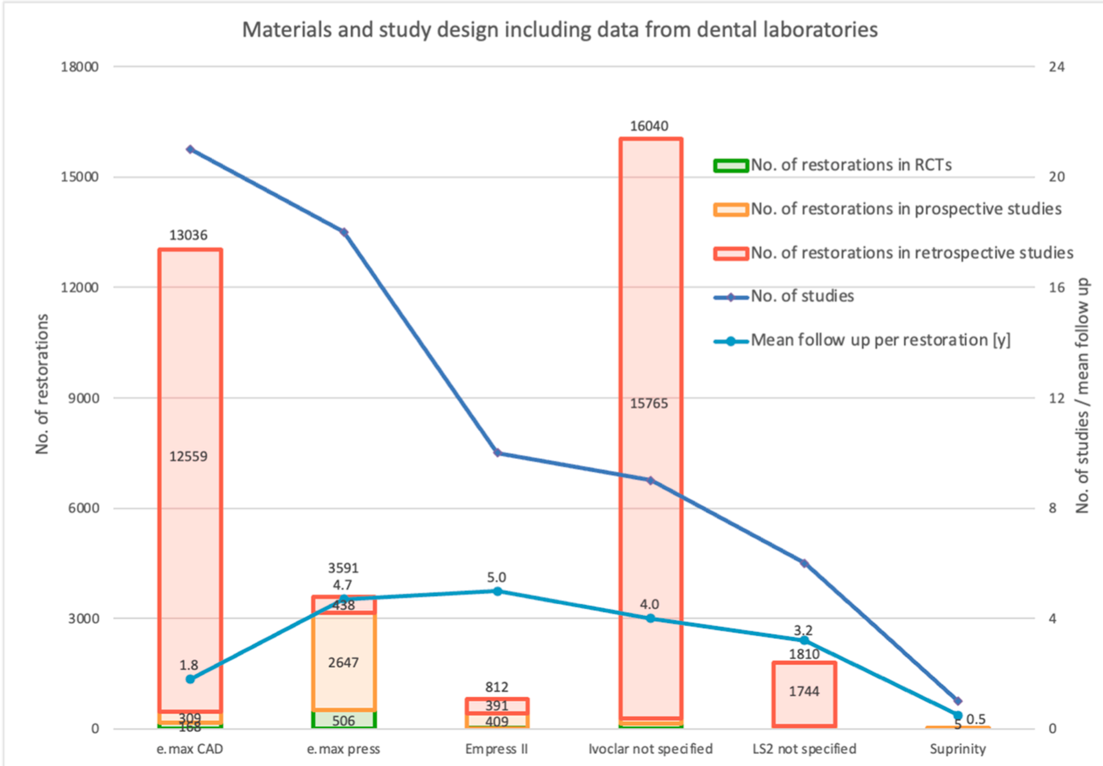

Fig. 2b. Materials and study design including data from dental laboratories.

	Al-Dulaijan 2023	Al-Haj Husain 2020	Aldegheishem 2017	AlMashaan & Aldakheel 2022	Araujo 2016	Aswal 2023	Aziz 2020	Benli 2022	Conrad 2007	Ferrairo 2024	Flores-Ferreyra 2024	Hmaidouch 2013	Kassardjian 2016	Mao 2024	Maroulakos 2019	Mazza 2021	Pieger 2014	Rodrigues 2019	Sailer 2015	De Souza Melo 2018	Vagropoulou 2018	Velastegui 2022
Al-Haj Husain 2020	25.0%																					
Aldegheishem 2017	8.3%	14.3%																				
AlMashaan & Aldakheel 2022	29.6%	25.0%	10.0%																			
Araujo 2016	8.3%	11.1%	33.3%	30.0%																		
Aswal 2023	4.8%	11.1%	0.0%	5.6%	0.0%																	
Aziz 2020	21.1%	40.0%	0.0%	20.0%	0.0%	33.3%																
Benli 2022	5.0%	11.1%	0.0%	0.0%	0.0%	0.0%	14.3%															
Conrad 2007	0.0%	0.0%	0.0%	50.0%	50.0%	0.0%	0.0%	0.0%														
Ferrairo 2024	27.3%	45.5%	16.7%	19.0%	14.3%	9.1%	16.7%	0.0%	0.0%													
Flores-Ferreyra 2024	10.0%	10.0%	0.0%	5.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%												
Hmaidouch 2013	14.3%	0.0%	0.0%	11.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	33.3%											
Kassardjian 2016	10.0%	12.5%	50.0%	22.2%	66.7%	0.0%	0.0%	0.0%	0.0%	20.0%	0.0%	0.0%										
Mao 2024	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	33.3%	0.0%	0.0%									
Maroulakos 2019	25.0%	26.7%	10.0%	21.1%	9.1%	0.0%	13.3%	8.3%	0.0%	12.5%	8.3%	25.0%	10.0%	0.0%								
Mazza 2021	15.8%	30.0%	0.0%	11.8%	0.0%	14.3%	57.1%	16.7%	0.0%	8.3%	0.0%	0.0%	0.0%	0.0%	23.1%							
Pieger 2014	50.0%	44.4%	0.0%	45.5%	0.0%	12.5%	25.0%	0.0%	0.0%	22.2%	25.0%	25.0%	0.0%	0.0%	20.0%	25.0%						
Rodrigues 2019	0.0%	12.5%	0.0%	0.0%	0.0%	50.0%	16.7%	0.0%	0.0%	14.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%					
Sailer 2015	16.7%	9.1%	20.0%	40.0%	60.0%	16.7%	12.5%	0.0%	50.0%	12.5%	0.0%	0.0%	40.0%	0.0%	9.1%	14.3%	18.2%	0.0%				
De Souza Melo 2018	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	18.2%	0.0%	0.0%	0.0%	0.0%			
Vagropoulou 2018	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	7.7%	0.0%	0.0%	0.0%	0.0%	25.0%		
Velastegui 2022	4.8%	10.0%	0.0%	5.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	50.0%	0.0%	0.0%	33.3%	8.3%	0.0%	12.5%	0.0%	0.0%	0.0%	0.0%	
Wang 2012	0.0%	0.0%	0.0%	50.0%	50.0%	0.0%	0.0%	0.0%	50.0%	0.0%	0.0%	20.0%	25.0%	0.0%	25.0%	0.0%	25.0%	0.0%	60.0%	0.0%	0.0%	0.0%

253	=	Total nodes (pairs of reviews)
149	=	Slight overlap (<5%)
15	=	Moderate overlap (5% to <10%)
27	=	High overlap (10% to <15%)
62	=	Very High overlap (>15%)

Fig. 3a. Graphical Representation of Overlap for OVErviews (GROOVE) – TS SCs.

	Benli 2022	Lemos 2024	Pjetursson 2021	Rabel 2018	Spitznagel 2017
Lemos 2024	0.0%				
Pjetursson 2021	0.0%	33.3%			
Rabel 2018	0.0%	36.4%	36.4%		
Spitznagel 2017	0.0%	14.3%	0.0%	11.1%	
Spitznagel 2022	0.0%	23.1%	5.9%	9.1%	20.0%

15	=	Total nodes (pairs of reviews)
6	=	Slight overlap (<5%)
2	=	Moderate overlap (5% to <10%)
2	=	High overlap (10% to <15%)
5	=	Very High overlap (>15%)

Fig. 3b. Graphical Representation of Overlap for OVErviews (GROOVE) – IS SCs.

Table 3
Complications.

Type of complication / failure	TS SCs																								IS SCs							
	Al-Dulaijan, 2023	Al-Haj Husain, 2020	Aldegheishem, 2017	AlMashaan & Aldakheel, 2023	Araujo, 2016	Aswal, 2023	Aziz, 2020	Benli, 2022	Conrad, 2007	Ferrairo, 2024	Flores-Ferreyra, 2024	Hmaidouch, 2013	Kassardjian, 2016	Mao, 2024	Maroulakos, 2019	Mazza, 2021	Pieger, 2014	Rodrigues, 2019	Sailer, 2015	de Souza Melo, 2018	Vagropoulou, 2018	Velastegui, 2022	Wang, 2012	**Sum TS**	Benli, 2022	Lemos, 2024	Pjetursson, 2021	Rabel, 2018	Spitznagel, 2017	Spitznagel, 2022	**Sum IS**	**Total**
Technical	0	2	1	0	2	5	3	1	3	5	0	0	0	0	3	4	2	0	0	2	2	0	2	37	0	5	5	4	2	3	19	56
Crown / core fracture		x	x		x	x	x	x	x	x					x	x	x			x	x		x	14		x	x	x		x	4	18
Fracture of veneering material / chipping					x	x			x	x					x	x	x			x			x	9		x	x	x	x	x	5	14
Loss of retention / debonding						x	x		x	x					x	x					x			7		x	x	x			3	10
Marginal discrepancies						x	x			x														3							0	3
Proximal contact defect						x										x								2							0	2
Abutment / post fracture		x								x														2		x	x			x	3	5
Abutment / screw loosening																								0		x	x	x			3	3
Occlusal roughness																								0					x		1	1
Anatomic form																								0							0	0
Biological	4	3	2	0	3	4	0	1	2	4	0	0	0	0	6	3	0	0	0	0	2	0	0	34	1	0	2	0	0	0	3	37
Loss of vitality/ endodontic complication	x	x	x		x	x		x	x	x					x	x					x			11							0	11
Secondary caries	x	x	x		x	x				x					x	x								8							0	8
Abutment tooth fracture		x			x	x			x	x					x	x					x			8							0	8
Extraction of abutment tooth															x									1							0	1
Periodontal problem / Peri-implantitis	x									x					x									3	x						1	4
Post-operative sensitivity	x					x									x									3							0	3
Soft tissue issues																								0			x				1	1
Bone issues																								0			x				1	1
Aesthetical	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Marginal discoloration						x																		1							0	1
Total	4	5	3	0	5	10	3	2	5	9	0	0	0	0	9	7	2	0	0	2	4	0	2	72	1	5	7	4	2	3	22	94

the importance of thorough polishing of occlusal surfaces after any chairside adjustments. Flores-Ferreyra et al. [89] noted a lack of sufficient clinical data to conclusively rank $LiSi_{(2)}$, but reported the least enamel wear for polished zirconia.

4.6. CAD/CAM vs. conventional fabrication methods

Five systematic reviews addressed the clinical survival and complications of $LiSi_{(2)}$ SCs fabricated using CAD/CAM techniques. Overall, no clinically relevant differences in survival or complications were found between the two manufacturing techniques. Aswal et al. [85] reported comparable biological and technical outcomes, although aesthetic shortcomings occurred significantly more frequent in CAD/CAM restorations. In their review, the clinical performance of $LiSi_{(2)}$ was significantly better than that of zirconia crowns. Aziz et al. [90] found high short- to medium-term survival rates for CAD/CAM $LiSi_{(2)}$ crowns, with biological complications occurring more frequently than technical ones. Al-Haj Husain et al. [91] observed decreased success rates after 3 or more years compared to 2 years and that full crowns performed better than partial crowns. It is important to acknowledge that the meta-analysis included a wide range of materials and that certain evaluations exhibited a high degree of heterogeneity. Rodrigues et al. [92] concluded that, across all materials, conventionally fabricated crowns exhibited a slightly lower risk of failure compared to CAD/CAM restorations. However, for CAD/CAM and press-fabricated $LiSi_{(2)}$ SCs, the success rates were comparable over time.

Benli et al. [93] showed that $LiSi_{(2)}$ crowns produced using digital impressions and CAD/CAM technology achieved good clinical performance, and also observed that monolithic crowns showed fewer complications compared to veneered designs.

4.7. Methodological quality

The sixteen domains of the AMSTAR 2 assessment tool were fulfilled, on average, to 55 % (± 23 %) ranging from 9 % to 88 %, the critical domains (2, 4, 7, 9, 11, 13, 15) to 57 % (± 31 %) ranging from 7 % to 100 % (Table 4). Overall confidence was critically low in 14, low in 10 and moderate in 4 SRs. Domains 3 (explanation for the selection of study design) and 10 (disclosure of funding sources for included studies) were particularly rarely fulfilled. Furthermore, the assessment and discussion of risk of bias and heterogeneity were frequently neglected (Fig. 4). A discernible improvement in fulfillment was observed over the years (Fig. 5).

Risk of bias was primarily assessed using the Cochrane tools RoB 2 [94] for RCTs and ROBINS-I [95], or the Newcastle-Ottawa-Scale (NOS) [96] for non-randomized clinical studies. In some cases, these tools were improperly applied; for example, tools designed for non-randomized studies were used in RCTs [93,97], and vice versa [87,90]. A total of nineteen reviews (61 %) employed instruments to assess risk of bias, but only thirteen of these reviews incorporated a discussion of bias and its influence was rarely considered in the meta-analyses.

Additional methodological weaknesses included treating follow-up studies as independent entities within meta-analyses or qualitative syntheses [91,97,98]. Suboptimal adherence to inclusion criteria [93,99,100], and errors in data extraction and citation [62,97,101] were also observed.

4.8. Disclosure of conflict of interest and funding

The reviews demonstrated varying levels of transparency regarding conflicts of interest. Notably, 32 % of reviews did not disclose any

Table 4
AMSTAR 2 results.

Author \ Domain	1 Components of PICO	2 Review protocol	3 Explanation for selection of study design	4 Comprehensive literature strategy	5 Study selection in duplicate	6 Data extraction in duplicate	7 List of excluded studies and justified the exclusions	8 Study characteristics in adequate detail	9 Satisfactory technique for assessing ROB	10 Sources of funding of included studies	11 Appropriate methods for conducting meta-analysis	12 Assessed potential impact of ROB on the results	13 Accounted for ROB when interpreting/ discussing	14 Satisfactory explanation and discussion of heterogeneity	15 Publication bias assessed and discussed	16 Conflict of interest declared	Score Yes = 1, No = 0 Partial Yes = 0.5 Max. 16 (no MA: 13)	%	Score critical Critical domains Yes = 1, No = 0 Partial Yes = 0.5 Max. 7 (no MA: 5)	%	Overall confidence
Al-Dulaijan, 2023	Yes	Partial Yes	No	Partial Yes	Yes	Yes	No	Yes	Yes	No	No meta-analysis	No meta-analysis	No	No	No	Yes	7,0	54%	2,0	40%	critically low
Al-Haj Husain, 2020	Yes	No	No	Partial Yes	Yes	Yes	No	Yes	Yes	No	No	No	No	No	Yes	Yes	7,5	47%	2,5	36%	critically low
Aldegheishem, 2017	No	No	No	Partial Yes	Yes	Yes	Yes	Yes	No	No	Yes	No	No	Yes	No	Yes	7,5	47%	2,5	36%	critically low
AlMashaan & Aldakheel, 2023	Yes	No	No	Yes	Yes	Yes	No	Yes	Partial Yes	No	No meta-analysis	No meta-analysis	No	No	No meta-analysis	Yes	6,5	50%	1,5	30%	critically low
Araujo, 2016	No	Partial Yes	No	No	Yes	No	Yes	Partial Yes	No	No	No meta-analysis	No meta-analysis	No	No	No meta-analysis	No	3,0	23%	1,5	30%	critically low
Aswal, 2023	Yes	Partial Yes	No	Yes	No	No	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	10,5	66%	5,5	79%	low
Aziz, 2020	Yes	Partial Yes	No	Partial Yes	Yes	No	Yes	Yes	Partial Yes	No	No meta-analysis	No meta-analysis	No	No	No meta-analysis	Yes	6,0	46%	2,5	50%	low
Benli, 2022	Yes	Partial Yes	No	No	Yes	No	No	Yes	Partial Yes	No	No meta-analysis	No meta-analysis	No	No	No meta-analysis	No	4,0	31%	1,0	20%	critically low
Conrad, 2007	No	No	No	Partial Yes	No	No	No	Yes	No	No	No meta-analysis	No meta-analysis	No	No	No meta-analysis	No	1,5	9%	0,5	7%	critically low
Ferrairo, 2024	Yes	Yes	No	Partial Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	12,5	78%	5,5	79%	low
Flores-Ferreyra, 2024	Yes	Yes	No	Partial Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	13,5	84%	6,5	93%	moderate
Hmaidouch, 2013	No	Partial Yes	No	No	Yes	No	No	Yes	No	No	No meta-analysis	No meta-analysis	No	No	No meta-analysis	No	2,5	19%	0,5	10%	critically low
Kassardjian, 2016	No	No	No	Partial Yes	Yes	No	No	No	No	No	Yes	No	No	Yes	Yes	No	4,5	28%	2,5	36%	critically low
Lemos, 2024	No	Yes	No	Partial Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No	No	9,5	59%	5,5	79%	low
Mao, 2024	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	14,0	88%	7,0	100%	moderate
Maroulakos, 2019	Yes	Yes	No	Partial Yes	Yes	Yes	Yes	Yes	Yes	No	No meta-analysis	No meta-analysis	Yes	Yes	No meta-analysis	No	9,5	73%	4,5	90%	moderate
Mazza, 2021	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	13,0	81%	6,0	86%	low
Pieger, 2014	No	No	No	Partial Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	No	No	No	No	5,5	34%	1,5	21%	critically low
Pjetursson, 2021	Yes	Partial Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	No	No	Yes	10,5	66%	5,5	79%	low
Rabel, 2018	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	Yes	12,0	75%	6,0	86%	low
Rodrigues, 2019	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	14,0	88%	6,0	86%	low
Sailer, 2015	Yes	No	No	Yes	Yes	Yes	Yes	Yes	No	No	Yes	No	No	No	No	Yes	8,0	50%	3,0	43%	critically low
de Souza Melo, 2018	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	12,0	75%	6,0	86%	low
Spitznagel, 2017	Yes	No	No	Yes	Yes	No	Yes	Yes	No	No	No meta-analysis	No meta-analysis	No	No	No meta-analysis	Yes	6,0	46%	2,0	40%	critically low
Spitznagel, 2022	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	Yes	11,0	69%	6,0	86%	low
Vagropoulou, 2018	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No meta-analysis	No meta-analysis	Yes	No	No meta-analysis	Yes	11,0	85%	5,0	100%	moderate
Velastegui, 2022	Yes	Yes	No	Partial Yes	Yes	No	No	Yes	Partial Yes	No	Yes	No	No	No	No	Yes	7,0	44%	4,0	57%	critically low
Wang, 2012	No	No	No	Partial Yes	Yes	Yes	No	Partial Yes	No	No	No	No	No	No	No	Yes	4,0	25%	0,5	7%	critically low
Compliance with domains [%] (Yes=1, Partial Yes=0.5, No=0)	71%	55%	4%	66%	93%	64%	61%	93%	61%	14%	78%	44%	46%	36%	39%	68%	mean	55%	mean	57%	

MA – meta-analysis.

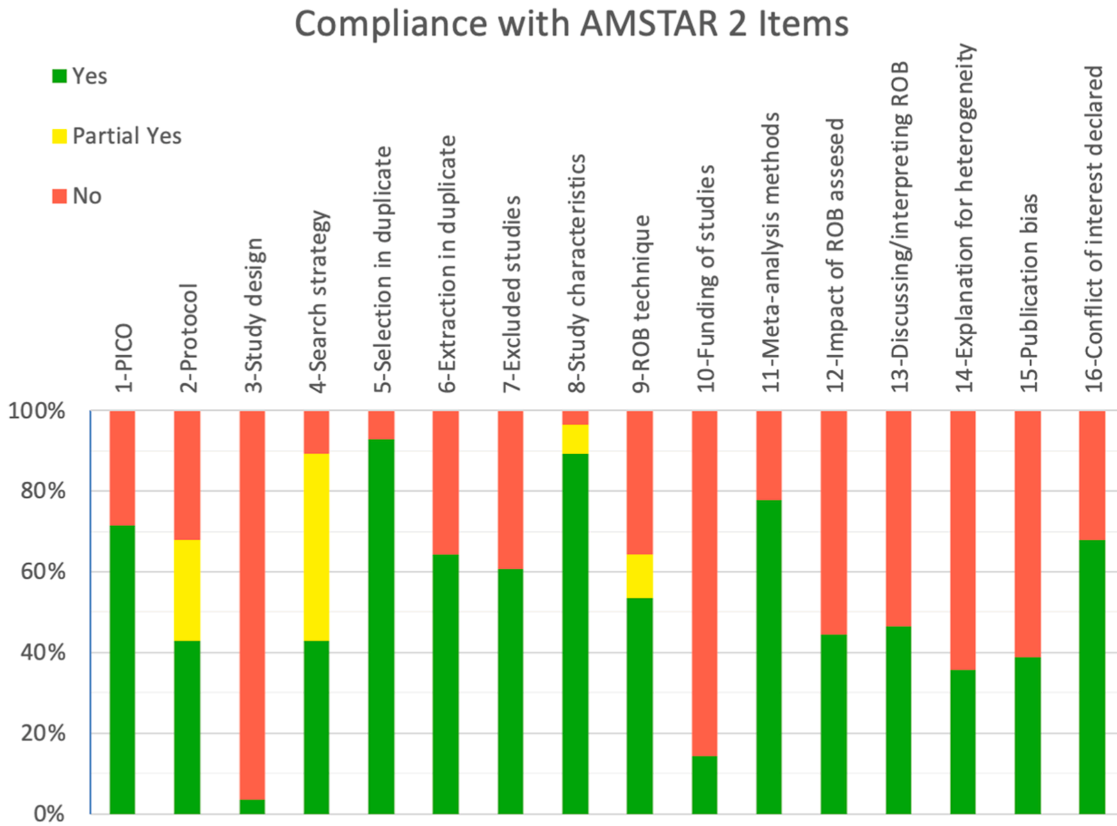

Fig. 4. Compliance with AMSTAR 2 Items.

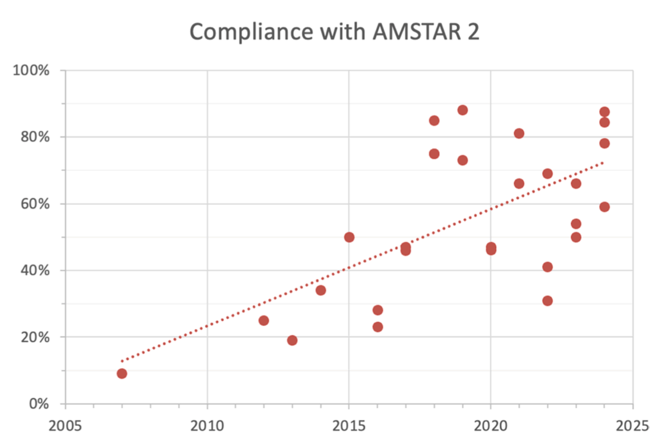

Fig. 5. Compliance of systematic reviews with AMSTAR 2 depending on year of publication.

potential conflicts, and only the minority [63,80,83,92] reported funding sources for the assessed studies. Analysis of primary studies revealed that 47 % did not disclose funding sources; 34 % received industrial sponsorship, 11 % reported public grants or sponsorship, and only 8 % declared no external founding.

5. Discussion

Recent systematic reviews consistently demonstrated excellent short- to medium-term survival rates for $LiSi_{(2)}$ SCs, with 1- to 5-year rates ranging from 95 % to 100 % [63,65]. Significant gaps exist, particularly regarding long-term outcomes beyond 5 years, which are underrepresented in the current literature. Only a few prospective studies have reported survival outcomes between 6 and 13 years, with cumulative survival rates declining modestly over time [14,39,61].

Technical complications, primarily chipping and restoration fractures, were infrequent for monolithic $LiSi_{(2)}$ restorations. Biological complications such as secondary caries, periodontal disease, or tooth fractures were of low incidence but not negligible. The variation in the results reflects heterogeneity in patient populations, prosthodontic procedures, and follow-up periods. The lack of uniform definitions and observed inconsistency in the use of evaluation criteria across studies, including the frequent omission of such information, undermines standardization and limits comparability. Notably, the more comprehensive and sensitive FDI criteria - which allow a more nuanced assessment of clinical performance - were rarely applied, highlighting a need for broader implementation in future studies [102].

Significantly more studies on tooth wear examine zircon and metal-ceramic than $LiSi_{(2)}$. The few studies on $LiSi_{(2)}$ show, that antagonist tooth wear caused by $LiSi_{(2)}$ restorations was minimal and comparable to natural enamel when polished surfaces were ensured [54,58,103,104]. Nonetheless, limited in vivo data especially beyond 24 months restricts definitive conclusions.

In the last years, there has been a strong increase in $LiSi_{(2)}$ materials on the market, with over 30 different products now available (Table 5) This raises the question of the comparability of the materials and the clinical studies. Recent research provides a deeper understanding of the microstructural evolution and mechanical properties of lithium silicate glass-ceramics. Studies employing advanced material testing methods like X-ray Fluorescence Spectroscopy, X-ray Diffraction, Field-Emission Scanning Electron Microscopy (SEM) or Resonant Ultrasound Spectroscopy reveal a detailed picture of the crystalline fraction, glass phase composition, and fracture toughness behavior of these materials. A key insight from these analyses is the variation in crystal phase compositions across different commercial products. While some exhibit predominant $LiSi_{(2)}$ phases, others contain significant amounts of lithium metasilicate, lithium phosphate, or even silica polymorphs such as quartz or

Table 5
Product specifications (see Appendix 6 for more details).
If conflicting information was found across different manufacturer sources, the data provided in the official instructions for use (IFU) was prioritized whenever available. [a]Stawarczyk [116] [b]Hallmann [117] [c]Yin [118].

Product name	Manufacturer	Introduction	Material	Processing	Flexural strength (MPa)	Vickers hardness [GPa]	Fracture toughness K_{IC} [MPa*m-0.5]	Indication
Empress® 2	Ivoclar Vivadent AG (Liechtenstein)	1998	$LiSi_{(2)}$	pressable	350±50		3.2	SC/PC/V/I/O/3B
IPS e.max® CAD	Ivoclar Vivadent AG (Liechtenstein)	2005	$LiSi_{(2)}$	two-step CAD/CAM	≥360, "typical mean value" according to manufacturer 530	5.8	2.0–2.5	SC/PC/V/I/O/OV/A/HA/HAC/3B
IPS e.max® Press	Ivoclar Vivadent AG (Liechtenstein)	2005	$LiSi_{(2)}$	pressable	≥360, "typical average value" according to manufacturer 470	6.1[b]	2.5–3.0	SC/PC/V/I/O/OV/A/HA/HAC/3B
Celtra® Duo	Dentsply Sirona Inc. (USA)	2013	ZLS	one/two-step CAD/CAM	210 (after polishing) / 370 (after glaze firing)	6.9	2.0	Polishing only: I/O after glaze firing: +SC/V
Celtra® Press	Dentsply Sirona Inc. (USA)	2016	ZLS	pressable	>500	6.1[b]	2.36[a] (Power fired)	SC/PC/V/I/O/OV/3B
Suprinity® (PC)	Vita Zahnfabrik H. Rauter GmbH & Co. KG (Germany)	2013 (PC: 2016)	ZLS	two-step CAD/CAM	420	7	2.0	SC/PC/IC/V/I/O
Initial™ LiSi Block	GC Corp. (Japan)	2021	$LiSi_{(2)}$	one/two-step CAD/CAM	408	6.3		SC/PC/IC/V/I/O
Initial™ LiSi Press	GC Corp. (Japan)	2017	$LiSi_{(2)}$	pressable	508	5.9/6.4[b]	2.38[a]	SC/V/TV/I/O/3B
Amber® Mill	HASS Corp. (South Korea)	2018	$LiSi_{(2)}$	two-step CAD/CAM	450±42	6.5	2.1±0.3	SC/PC/V/TV/I/O/3B
Amber® Mill Direct	HASS Corp. (South Korea)	2022	$LiSi_{(2)}$	one/two-step CAD/CAM	>300 (avg. 355 after glaze firing)			SC/V/I/O
Amber® Mill Q	HASS Corp. (South Korea)	2019	$LiSi_{(2)}$ with zirconia core	CAD/CAM	>300			IC/A
Amber® Press	HASS Corp. (South Korea)	2018	$LiSi_{(2)}$	pressable	460±25		2.86[a]	SC/PC/V/TV/I/O/3B
Amber® Press Master	HASS Corp. (South Korea)		$LiSi_{(2)}$	pressable	>300			SC/PC/V/TV/I/O/3B
Amber® LiSi-POZ	HASS Corp. (South Korea)	2018	$LiSi_{(2)}$	pressable on zirconia framework	380			SC/IC/3B/IB
Amber® LiSi-POM	HASS Corp. (South Korea)		$LiSi_{(2)}$	pressable on metal framework	NR			SC/V/I/O/3BA
Rosetta® SP	HASS Corp. (South Korea)		$LiSi_{(2)}$	pressable	460			SC/PC/V/TV/I/O/3B
Rosetta® SM	HASS Corp. (South Korea)		$LiSi_{(2)}$	CAD/CAM	440			SC/PC/V/TV/I/O/3BA
N!CE®	Straumann AG (Switzerland)	2016	LAS	one/two-step CAD/CAM	350±50		≥ 1.5	SC/PC/IC/V/I/O
Obsidian® Milling Blocks	Glidewell Laboratories (USA)	2016	$LiSi_{(2)}$	two-step CAD/CAM	385±45		1.47±0.19	SC/PC/V/I/O
CEREC Tessera™	Dentsply Sirona Inc. (USA)	2020	$LiSi_{(2)}$	two-step CAD/CAM	>700			SC/V/I/O
Livento® press	Cendres + Métaux (Switzerland)	2018	$LiSi_{(2)}$	pressable	400±50		2.25/2.67[a]	SC/PC/IC/V/TV/I/O/3B
Vintage LD Press	SHOFU Dental GmbH (Germany)	2015	$LiSi_{(2)}$	pressable	377			SC/PC/IC/V/TV/I/O/3B
DC Ceram™ ConceptPress	CERAMAY (Germany)	2017	$LiSi_{(2)}$	pressable	420		2.25	SC/PC/IC/V/TV/I/O/OV/3B
Up.CAD	Upcera (China)		$LiSi_{(2)}$	CAD/CAM	≥400			
Up.PRESS	Upcera (China)		$LiSi_{(2)}$	pressable				
T-lithium	Talmax (Brazil)		$LiSi_{(2)}$					
AIDITE	Shenzhen (China)		$LiSi_{(2)}$					
IRIS	Tianjin (China)		$LiSi_{(2)}$					
Dentitude Press	Fuzhou Brown (China)		$LiSi_{(2)}$	pressable	470	6.3	2.2	
Dentitude CAD/CAM Blocks	Fuzhou Brown (China)		$LiSi_{(2)}$	CAD/CAM	420	6.0	2.0	
Vivid GlassMax HAT	Vivid by Pearson		$LiSi_{(2)}$	CAD/CAM		5.4 ± 0.4		
Vivid Pressable Ceramic	Vivid by Pearson		$LiSi_{(2)}$	pressable				

3B – 3-unit bridges up to second premolar; 3BA – 3-unit anterior bridges; A – abutment; CB – cantilever bridge; HA – hybrid abutment; HAC – hybrid abutment crown; IB – implant supported bridges; I – inlay; IC – implant crown; MB – maryland bridge; O – onlay; OV – occlusal veneer; PC – partial crown; SC – single crown; TV – thin veneer; V – veneer; ZLS – zirconia reinforced lithium silicate.

cristobalite, influencing mechanical stability and wear resistance [12, 105]. Different crystalline compositions and mechanical properties may lead to differing clinical behavior [8]. It can therefore be assumed that the results of clinical studies on a specific product cannot simply be transferred to the wide range of $LiSi_{(2)}$ systems now available on the market. Therefore, a key limitation identified is that almost all clinical data originate from studies evaluating IPS e.max products. Only one study [103] specified the use of other $LiSi_{(2)}$ materials, and when unspecified, a strong likelihood of IPS e.max usage can be assumed due to market dominance.

Current evidence fails to address the broader anatomical and functional consequences of $LiSi_{(2)}$ restorations on the stomatognathic system. Analogous to zirconia restorations [23], it remains unclear whether $LiSi_{(2)}$ crowns could impact occlusal dynamics, masticatory muscle function, or temporomandibular health over longer periods.

In addition, economic evaluations are lacking. No systematic review provided robust data comparing cost-effectiveness between $LiSi_{(2)}$ and other materials such as zirconia or metal-ceramics.

The results highlight substantial variability in methodological rigor among the included systematic reviews. While a subset achieved medium confidence ratings according to AMSTAR 2, the majority were rated as low or critically low in overall quality. Key deficits were observed in areas such as prospective protocol registration, justification of study designs, and inadequate consideration of risk of bias during evidence synthesis. Although some reviews formally assessed bias using established tools (RoB 2, ROBINS-I, NOS), its impact was rarely discussed or incorporated into meta-analyses. This is problematic, as bias can significantly distort effect estimates.

Meta-analyses were performed with very different materials and restorations - hybrid polymers to zirconia and veneers to crowns. This led to results with high heterogeneity (I^2 often >80 %) [91], undermining the robustness of pooled estimates. Without further investigations such as subgroup or sensitivity analyses, such results with extremely high inconsistency do not provide reliable information [106].

This has direct implications for the interpretability and clinical applicability of their findings. While the methodological quality of systematic reviews has improved over time with the incorporation of PRISMA and AMSTAR 2 guidelines, many reviews still failed to fully incorporate risk of bias assessments into their meta-analyses, compromising the reliability of pooled results [32,106,107]. The overall trend underscores the necessity for stricter adherence to systematic review standards and better reporting practices, especially when informing clinical decision-making in evidence-based dentistry.

Another factor that limits the reliability of the findings in this overview is the high overlap of primary studies among the included reviews - despite its broad scope. Such overlap can result in redundancy, an artificial inflation of the perceived strength of evidence, and a disproportionate representation of certain studies, particularly when multiple meta-analyses are based on the same underlying datasets. This may create a misleading impression of consistency or robustness across reviews, especially when a few dominant trials drive the results of several analyses [108].

Given the typical lag of 1–3 years between literature search and publication in systematic reviews, there is a risk that newly published studies are not captured, potentially biasing conclusions. Best practice, therefore, mandates that literature searches be updated immediately prior to publication, as recommended by PRISMA guidelines.

Additionally, transparency regarding conflicts of interest and funding was often insufficient, both at the review and primary study level. Industrial sponsorship was declared in 34 % of primary studies, but nearly half failed to disclose any funding source, raising concerns about the potential for bias. Independent, high-quality prospective studies are essential to advance understanding, but their execution demands considerable financial and logistical resources. Given limited public funding, industrial sponsorship often becomes necessary. However, rigorous transparency regarding funding sources and potential conflicts of interest is critical to maintain scientific integrity.

5.1. Strengths and limitations

This overview has several strengths. It was conducted based on a prospectively published protocol and adheres to established methodological standards, including PRISMA-P and PRIO-harms. The literature search was comprehensive and included five major databases without language or date restrictions, supplemented by backward and forward citation tracking. The methodological quality of included SRs was evaluated using AMSTAR 2, and the certainty of evidence was assessed using the GRADE approach. Potential sources of bias, including study overlap, publication bias, and sponsorship, were systematically addressed using structured tools such as GROOVE.

However, several limitations must also be considered. No independent meta-analyses were performed in this overview. Instead, pooled estimates and meta-analyses from the included reviews were adopted, limiting the ability to perform tailored subgroup or sensitivity analyses. While heterogeneity was transparently reported and discussed, no formal statistical exploration (e.g., meta-regression) was undertaken. Furthermore, a large proportion of primary data originated from a single $LiSi_{(2)}$ system (IPS e.max), potentially limiting the applicability of results to other commercially available materials. The quality and reporting transparency of the included primary studies were variable, with frequent omissions in the disclosure of conflicts of interest and funding sources. These factors may introduce residual uncertainty and underscore the need for high-quality, prospective, independently funded clinical studies on newer $LiSi_{(2)}$ systems.

5.2. Certainty of evidence (GRADE assessment)

The GRADE assessment further underscores the limitations of the available evidence. The overall certainty of evidence was rated as moderate for survival. Survival rates were consistently high across a large number of prospective and retrospective studies. Despite methodological limitations - particularly the predominance of observational data and heterogeneity - this outcome retained a moderate level of certainty due to the large sample size and consistency of findings.

In contrast, the certainty of evidence was downgraded to low for technical and biological complications, as well as antagonist tooth wear, due to frequent methodological shortcomings, including incomplete or absent risk of bias assessments, inconsistent outcome definitions, and imprecise reporting. For aesthetic complications the certainty of evidence was downgraded to very low, as the evidence was particularly sparse and highly heterogeneous, with few studies explicitly defining aesthetic endpoints or variation in evaluation criteria.

Across all domains, the lack of standardized definitions and the overwhelming concentration of data on a single material (IPS e.max) limit generalizability and reinforce the need for more diverse, high-quality research using harmonized methodologies. A detailed GRADE summary is provided in Table 6.

6. Conclusions

$LiSi_{(2)}$ crowns on teeth and implants offer high short- and medium-term survival and excellent aesthetic outcomes, irrespective of their manufacturing procedure. However, interpretation of the evidence must consider methodological heterogeneity, material-specific differences, and limited long-term data. Further prospective studies focusing on different $LiSi_{(2)}$ systems are needed.

Data availability

Data supporting this study have been deposited in Zenodo and are publicly available under the DOI https://doi.org/10.5281/zenodo.15597573 [26].

Table 6
Summary of Findings Table – GRADE (see Appendix 7 for detailed information).

Outcome	Certainty of Evidence (GRADE)	Study Design (No. of studies)	Summary of Findings	Justification/Comments
Survival	●●●° **moderate**	RCT (10), prospective (21), retrospective (10)	High survival in short- to medium-term (95–100 %), limited long-term data, high methodological heterogeneity	Downgraded for - risk of bias due to predominance of observational studies and inconsistant assessment - inconsistency due to heterogeneity in follow-up durations and settings - imprecision from sparse long-term data.
Technical complications	●●°° **low**	RCT (14), prospective (21), retrospective (12)	Fractures and chipping infrequent, but reporting and definitions highly variable, especially between monolithic and veneered restorations.	Downgraded for - risk of bias due to predominance of observational studies and inconsistant assessment - inconsistency due to heterogeneity in follow-up durations and settings and variation in definitions - imprecision (small subgroup sizes).
Biological complications	●●°° **low**	RCT (14), prospective (17), retrospective (10)	Biological complications like secondary caries and periodontal problems were rare but inconsistently reported.	Downgraded for - risk of bias due to predominance of observational studies and inconsistant assessment - inconsistency (variable endpoint definition) - imprecision (few studies with clinical focus on biological outcomes).
Aesthetic complications	●°°° **very low**	RCT (13), prospective (11), retrospective (10)	Marginal discoloration was the only frequently mentioned aesthetic drawback; reporting was inconsistent.	Downgraded across multiple domains due to very limited and inconsistent reporting; varying evaluation tools for aesthetics.
Antagonist tooth wear	●●°° **low**	RCT (4), prospective (4)	Polished $LiSi_{(2)}$ crowns caused minimal enamel wear; findings consistent across few small studies.	Downgraded due to limited number of studies, short observation periods, and sparse high-quality clinical data, despite consistent findings in favor of minimal wear.

The dataset includes a PRIO-harms checklist; complete and reproducible search strategies for all databases with accession numbers of the records found; PRISMA-S and TARCiS checklists for the search process; comprehensive lists of excluded reports, systematic reviews, primary studies, and dental products with descriptive details; structured evidence tables for GRADE, PICOS, AMSTAR 2, GROOVE classification, material frequency and summary of complications; as well as diagrams illustrating the number of publications per year, mean follow-up duration, disclosure of conflicts of interest and funding sources and all abbrevations used.

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CRediT authorship contribution statement

Harald Laumbacher: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Konstantin J Scholz:** Writing – review & editing, Visualization, Validation, Investigation, Data curation. **Helge Knüttel:** Writing – review & editing, Visualization, Validation, Resources, Methodology, Formal analysis, Data curation. **Martin Rosentritt:** Writing – review & editing, Validation, Resources, Methodology, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jdent.2025.106004.

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