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

Patrick Klein[1] | Frank A. Spitznagel[1] | Anja Zembic[2] | Lea S. Prott[1,3] | Stefano Pieralli[4] | Brenda Bongaerts[5] | Maria-Inti Metzendorf[5] | Robert Langner[6,7] | Petra C. Gierthmuehlen[1]

[1]Department of Prosthodontics, Medical Faculty and University Hospital Düsseldorf, Heinrich-Heine-University, Düsseldorf, Germany | [2]Private Practice, Winterthur, Switzerland | [3]Department of Preventive and Restorative Sciences, Penn Dental Medicine, University of Pennsylvania, Philadelphia, Pennsylvania, USA | [4]Department of Prosthodontics, Geriatric Dentistry and Craniomandibular Disorders, Charité-Universitätsmedizin Berlin, Corporate Member of Freie, Universität Berlin and Humboldt-Universität zu Berlin, Berlin, Germany | [5]Institute of General Practice, Medical Faculty of the Heinrich-Heine-University Düsseldorf, Düsseldorf, Germany | [6]Institute of Systems Neuroscience, Medical Faculty, Heinrich-Heine-University Düsseldorf, Düsseldorf, Germany | [7]Institute of Neuroscience and Medicine, Brain and Behavior (INM-7), Research Center Jülich, Jülich, Germany

**Correspondence:** Patrick Klein (patrick.klein@med.uni-duesseldorf.de)

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## ABSTRACT

**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).

**Material 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- [1–3 years], mid- [4–6 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.

Patrick Klein and Frank A. Spitznagel share the first authorship.

## 1 | Introduction

The esthetic appearance plays a crucial role in the psychological and social well-being of an individual with attractive people being more likely successful [1, 2]. In recent years, esthetic dentistry has seen a significant growth, driven by the increased use of social media sites and applications [3, 4]. Esthetic dental treatments, such as teeth whitening, orthodontic tooth corrections, and laminate veneer restorations are nowadays more frequently requested by patients, positively increased by social media [3].

Ceramic laminate veneers are a minimally invasive and well-established restorative technique, which allow appealing esthetics especially in cases of malformed, misaligned, discolored, fractured and worn teeth [5]. When selecting a suitable material for laminate veneers, both favorable optical and mechanical properties, with a low susceptibility towards complications are essential. In general, ceramic laminate veneers can be fabricated out of feldspathic porcelain, leucite-reinforced glass ceramics (LRGC), lithia-based glass ceramics, mainly lithium disilicate (LDS) and resin-matrix-ceramics (RMC) [6]. Feldspathic porcelain and LRGC demonstrate superior esthetics, due to their ability to mimic a natural tooth with its own shade and translucency. However, both materials are associated with low mechanical properties [6]. LDS ceramics offer a balanced combination of advantageous esthetics and favorable mechanical strength, surpassing feldspathic porcelain and LRGC [7, 8]. With recent advancements in material properties and increased translucency, zirconia and its different generations offers a viable alternative material for laminate veneer fabrication [9, 10]. The success and long-term performance of laminate veneers depends on a minimal and mostly enamel-based preparation as well as a strong adhesive bond between the ceramic-tooth interface [11].

While glass ceramics contain a vitreous phase, that enables a strong adhesive bond through acid etching and silanization, resin bonding to zirconia can be challenging [6]. A combined micromechanical and chemical pretreatment with air-particle abrasion, primer application and utilization of composite cements ("APC concept") is recommended to ensure a durable bond to zirconia [12, 13].

In the past, laminate veneers were mainly fabricated using conventional methods, including refractory dies, platinum foil and heat-pressing, but nowadays Computer-Aided Design (CAD) / Computer-Aided Manufacturing (CAM) techniques have become more prevalent.

Systematic reviews reported estimated survival rates of 89% after 9 years and 95.5% after 10 years of observation for ceramic laminate veneers [14, 15]. Previous systematic reviews on ceramic laminate veneers explored factors influencing their survival and success, such as preparation design, cementation techniques and bonding substrates [14–20].

So far, no clear distinction between different type of ceramic materials including zirconia and their corresponding survival and complication rates, at short-, mid- and long-term observation periods has been made.

Therefore, the aim of the present systematic review was to assess the clinical performance and longevity of ceramic laminate veneers and to report on the incidence of technical, esthetic, and biological complications with specific focus on the different type of ceramic materials.

## 2 | Material and Methods

### 2.1 | Study Design

This systematic review was designed according to current Cochrane guidelines and followed the guidelines for Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [21, 22]. To ensure transparency and avoid duplication, the study protocol was registered at the National Health Institute for Research PROSPERO, International Prospective Register for Systematic Reviews under the PROSPERO-ID: CRD42024568719. An ethical approval was not required for the present systematic review. The focused clinical question for this systematic review was: "What are the survival and complication rates of ceramic laminate veneers being at least one-year in function?" In accordance with the research question, the PICO framework was customized and defined as: [23, 24]

- P (Patients): patients in need of indirect ceramic laminate veneer restorations on permanent anterior teeth and premolars (FDI notion 15–25 and 35–45)
- I (Intervention): ceramic laminate veneers being ≥ 1 year in function
- C (Comparison): not considered (prognosis as the primary arm)
- O (Outcome): survival and technical, esthetical and biological complications of laminate veneers

### 2.2 | Search Strategy

To identify relevant studies for this systematic review, a search strategy was developed by an experienced information scientist (MIM) based on a text analysis of 18 PubMed listed clinical studies known to the authors. The search was run from inception of each database up to February 19, 2024, in the following databases and study registers (Table 1): MEDLINE (via PubMed), the Cochrane Central Register of Controlled Trials (via Cochrane Library), Scopus, WHO International Clinical Trials Registry Platform and ClinicalTrials.gov. In addition, the reference lists of all included studies and recently published reviews [14–20, 25–27] on ceramic laminate veneers in anterior and premolar region were hand-searched to identify further potentially eligible studies.

### 2.3 | Selection of Studies

The search results of all databases were imported into a software application (Rayyan; www.rayyan.ai). Duplicates were removed using the Deduklick algorithm [28] and two of the authors (PK and SP) independently reviewed titles and abstracts to identify studies which meet the eligibility criteria (Table 2). In case title

**TABLE 1** | Search strategies of included databases.

| Search strategy | |
|---|---|
| MEDLINE via PubMed | #1<br>crown*[tw] OR onlay*[tw] OR overlay*[tw] OR inlay*[tw] OR veneer*[tw]<br>#2<br>"Dental Restoration, Permanent"[mh] OR restor*[tw]<br>#3<br>"Dental Restoration Failure"[mh] OR "Survival Analysis"[mh] OR "Survival Rate"[mh] OR survival[tw] OR fractures[tw]<br>#4<br>#1 AND #2 AND #3 = 5840 |
| Scopus (advanced search) | TITLE-ABS-KEY((crown* OR onlay* OR overlay* OR inlay* OR veneer*) AND restor* AND (failure OR survival OR fractures) AND (random* OR trial OR placebo OR groups) OR (cohort OR (control AND study) OR (control AND group*) OR OR {follow up} OR {time factors} OR CI)) = 5609 |
| Cochrane Central Register of Controlled Trials (via Cochrane Library), Issue 2 of 12, February 2024 | 1. (crown* OR onlay* OR overlay* OR inlay* OR veneer*):ti,ab,kw<br>2. [mh "Dental Restoration, Permanent"] OR restor*:ti,ab,kw<br>3. [mh "Dental Restoration Failure"] OR [mh "Survival Analysis"] OR [mh "Survival Rate"] OR (survival OR fractures):ti,ab,kw<br>4. #1 AND #2 AND #3 = 894 |
| ClinicalTrials.gov | ((crown OR crowns OR onlay OR onlays OR overlay OR overlays OR inlay OR inlays OR veneer OR veneers) AND (restore OR restored OR restoring OR restoration OR restorations) AND (failure OR survival OR fractures)) = 219 |
| WHO ICTRP | ((crown* OR onlay* OR overlay* OR inlay* OR veneer*) AND (restor*) AND (failure OR survival OR fractures)) = 30 |
| 18 relevant PubMed records (PMIDs) used to develop the search strategy | 30885576[PMID] OR 11921765[PMID] OR 31168916[PMID] OR 19841768[PMID] OR 35172796[PMID] OR 15736774[PMID] OR 33625392[PMID] OR 20038893[PMID] OR 23534025[PMID] OR 22821429[PMID] OR 31084936[PMID] OR 25010879[PMID] OR 31797334[PMID] OR 35329602[PMID] OR 29936052[PMID] OR 35793984[PMID] OR 25279393[PMID] OR 27263032[PMID] |

and abstract did not provide sufficient information to decide whether or not the study could be included, the full-text of the article was obtained and screened. All full-text articles of potentially eligible studies were independently assessed by two reviewers (PK and FS). The screened studies were compared and any disagreement was resolved by consensus or by involving a third author (PG). In case of insufficient information for data extraction and meta-analysis, the corresponding authors were contacted via e-mail.

## 2.4 | Data Extraction

Data extraction was performed by two review authors (PK and FS) individually on a specifically designed data extraction sheet for this review and then double-checked. Parameters for data extraction from the included studies were as followed: authors, year of publication, study type (randomized controlled trial [RCT], prospective or retrospective), initial number of patients, final number of patients at last follow-up, dropouts, number of restorations at baseline and number of restorations at last follow-up, mean follow-up time (years), location (jaw and tooth position), restoration material (feldspathic ceramic, LRGC, LDS, zirconia), preparation design (no-prep, window, feather, butt joint, palatal chamfer) [29, 30], total number of survived and failed units (number and percentage), tooth vitality (vital, non-vital), fabrication method (conventional or digital) and cementation mode (light- or dual-curing). Additionally, technical complications (crack, chipping, bulk fracture, debonding and marginal gap), esthetic complications (marginal discoloration) and biological complications (tooth fracture, secondary caries, endodontic complication, tooth loss) were recorded (number and percentage).

## 2.5 | Outcome Measures

The primary outcome of this review was the survival rate of ceramic laminate veneers. Additionally, technical, esthetic, and biological complications were investigated as secondary outcomes. To ensure consistency in the included studies the outcome measures were defined and established as followed:

- Laminate veneer survival was defined as the restoration remaining in situ at the final follow-up visit with or without the need for maintenance.
- Technical complications including cracks (minor crack lines), chipping (minor and major), bulk fracture (complete/catastrophic fracture, i.e., restoration needs to be replaced),

**TABLE 2** | Eligibility criteria.

| Inclusion criteria | Exclusion criteria |
|---|---|
| • Human trials<br>• Language restriction: English<br>• Peer-reviewed journals<br>• Study design: RCTs, prospective and retrospective observational studies and case series with 10 or more patients<br>• Studies with a mean follow-up time of at least 12 months in function<br>• Clinical examination of patients at follow-up visit<br>• In case of multiple studies reporting on the same study sample, only the most recent study was considered<br>• Applied materials still available on the dental market<br>• Applied materials containing ceramic particles (resin-matrix-ceramics) or being completely out of ceramics | • Case reports, case series with less than 10 patients, expert opinions, animal studies, in-vitro studies, poster abstracts, interviews or protocols<br>• Studies with the same sample<br>• Data extracted based on charts (no clinical examination of patients)<br>• Full crown restorations<br>• Restorations on molars<br>• Insufficient information on preparation design and/or clinical procedures<br>• Studies with clinically and scientifically not approved, experimental protocols (e.g., partial veneer/unusual bonding procedures)<br>• Studies with no or insufficient information on survival and complication rates for veneers/data extraction not possible<br>• Restorations on deciduous teeth |

debonding (single or multiple times of loss of retention) and marginal gaps (detectable crevice with probe).

- Esthetic complications including marginal discoloration (slight/superficial discoloration along the margin to severe staining with penetration along the margin).
- Biological complications including tooth fractures (minor crack lines up to crown fracture near the cement-enamel junction), secondary caries, endodontic complication (endodontic treatment necessary) and abutment tooth loss (need for abutment tooth extraction).

### 2.6 | Risk of Bias Assessment

Two authors (PK and FS) independently performed a risk of bias analysis of all included studies according to the Cochrane risk of bias Tool 2 (RoB 2.0) for randomized controlled clinical trials (RCTs) and according to MINOR (Methodological index for non-randomized studies) for observational prognosis studies [31, 32]. The Rob-2 tool scores five domains: (1) bias arising from the randomization process, (2) bias due to deviations from intended interventions, (3) bias due to missing outcome data, (4) bias in measurement of the outcome, and (5) bias in selection of the reported outcomes. The MINOR tool assessed eight to 12 domains according to the individual study design of non- and comparative observational studies with scores from 0 (not reported), 1 (reported but inadequate) to 2 (reported and adequate). The eight items for non-comparative studies included a clearly stated aim, inclusion of consecutive patients, prospective collection of data, endpoints appropriate to the aim of the study, unbiased assessment of the study endpoint, appropriate follow-up period according to the aim of the study, loss to follow-up and prospective calculation of the study size. The risk of bias was judged as low, some concern or high.

### 2.7 | Statistical Analysis

Survival rates according to the duration of the follow-up (short-, mid-, long-term) were calculated with the laminate veneer restoration being the statistical unit. The survival rates of laminate veneers were calculated by the number of survived units (numerator) divided by the number of laminate veneers at risk at follow-up periods (denominator). Additionally, event rates for technical, esthetic and biological complications were calculated according to the duration of the follow-up. Complication rates were assessed by the number of occurred events (numerator) divided by the number of laminate veneers at risk at follow-up periods (denominator). Raw proportion data were subsequently adjusted via arcsine-transformation according to Anscombe [33], whereby the continuity correction contained therein is recommended for extreme proportions (including 0 or 1) and variable sample sizes as in the included studies to perform meta-analysis. Standard errors (SEs) corresponding to the arcsine-transformed survival and complication rates, respectively, were calculated according to the duration of the follow-up.

Meta-analyses were performed using the software JASP (Version 0.19.0 – https://jasp-stats.org). A random-effects model as proposed by DerSimonian and Laird was employed to estimate all pooled data [34]. The extent and impact of between-study heterogeneity was assessed by inspecting the forest plots and by calculating the $I^2$ statistic. Subgroup analyses via meta-regression using the Wald-test (thresholded at $p < 0.05$) were performed to examine potential sources of heterogeneity with respect to the type of ceramic material used.

Funnel plots were generated (if 10 or more studies could be included for meta-analysis) and used to assess and graphically display reporting bias and to determine the link between effect size and SE in the meta-analysis. A parametric regression approach (Egger's test) was employed to evaluate the degree of funnel plot asymmetry [35].

## 3 | Results

### 3.1 | Screening Process

The initial literature search yielded in a total of 12,592 titles (Figure 1) and 14 records were additionally identified by screening reference lists. After de-duplication, 7913 titles were imported into Rayyan [28]. Following title and abstract screening a total of 98 articles were obtained for full-text analysis. Subsequently, 29 studies (Tables 3–5) were eligible for inclusion and analyzed for data extraction. Main reasons for exclusion of full-texts are given in Figure 1 and Table S1.

### 3.2 | Study Characteristics

Of the 29 publications included, two were RCTs [36, 37], 13 were prospective cohort studies [38–50] and 14 were retrospective clinical investigations [51–64] (Tables 3–5). From the two RCTs, a total of three eligible study arms met the inclusion criteria and were therefore processed for further analyses in the present systematic review [36, 37]. In total 29 clinical studies with 41 study arms were eligible for meta-analyses. Studies reported on four different material compositions, namely feldspar [38–41, 44, 46, 48, 50, 53, 56, 57, 61], LRGC [36, 42, 49, 56, 60, 62], LDS [37, 43, 45, 47, 51, 52, 54, 55, 58–60, 63, 64], and zirconia [64]. No publications could be identified for RMC.

A total of 7753 anterior ceramic laminate veneers were placed in 986 patients (age range: 17–87) and surveyed over a period of 1.0–20.7 years. Studies were published between 1994 and 2024 and performed both in institutional environments (universities) and private practices in the following countries: Belgium, Brazil, China, Germany, Italy, Iran, Netherlands, Poland, Spain, Switzerland, Turkey and USA. Out of the 41 study arms, 35 arms reported about ceramic laminate veneers which were produced with a conventional workflow with analog impressions and plaster casts, one study arm reported about a combination of a conventional-digital approach [37] and five study arms reported on a fully digital workflow including intraoral scanning as an impression technique [58, 60, 64]. The location of the laminate veneers was either solely in the maxilla or in both arches. None of the studies was investigating ceramic laminate veneers only in the mandible. Fourteen studies included also premolar laminate veneers, whereas 12 out of the 29 studies investigated only laminate veneers from canine to canine and three studies did not differentiate if premolars were included or not, reporting only on anterior teeth. Five different preparation designs for ceramic laminate veneers were applied: [26, 29] four study arms used a no-prep design [43, 48, 53, 57], one study arm a window preparation [39], one study arm a feather preparation [46], 21 study arms a butt-joint preparation [36–38, 40–43, 45, 47, 49, 51, 52, 55, 57–60] and six a palatal chamfer preparation [42, 47, 48, 50, 54, 55, 63]. The remaining eight study arms used a combination of different preparation designs, mostly feather and butt joint or butt-joint and palatal chamfer [44, 56, 61, 62, 64]. In respect to tooth vitality 12 study arms reported exclusively on vital teeth [38, 42, 49, 51, 53, 60, 62, 64], whereas 14 study arms included vital and non-vital abutment teeth [36, 39–41, 47, 48, 50, 55, 56, 63]. Fifteen study arms did not report on tooth vitality [37, 43–46,

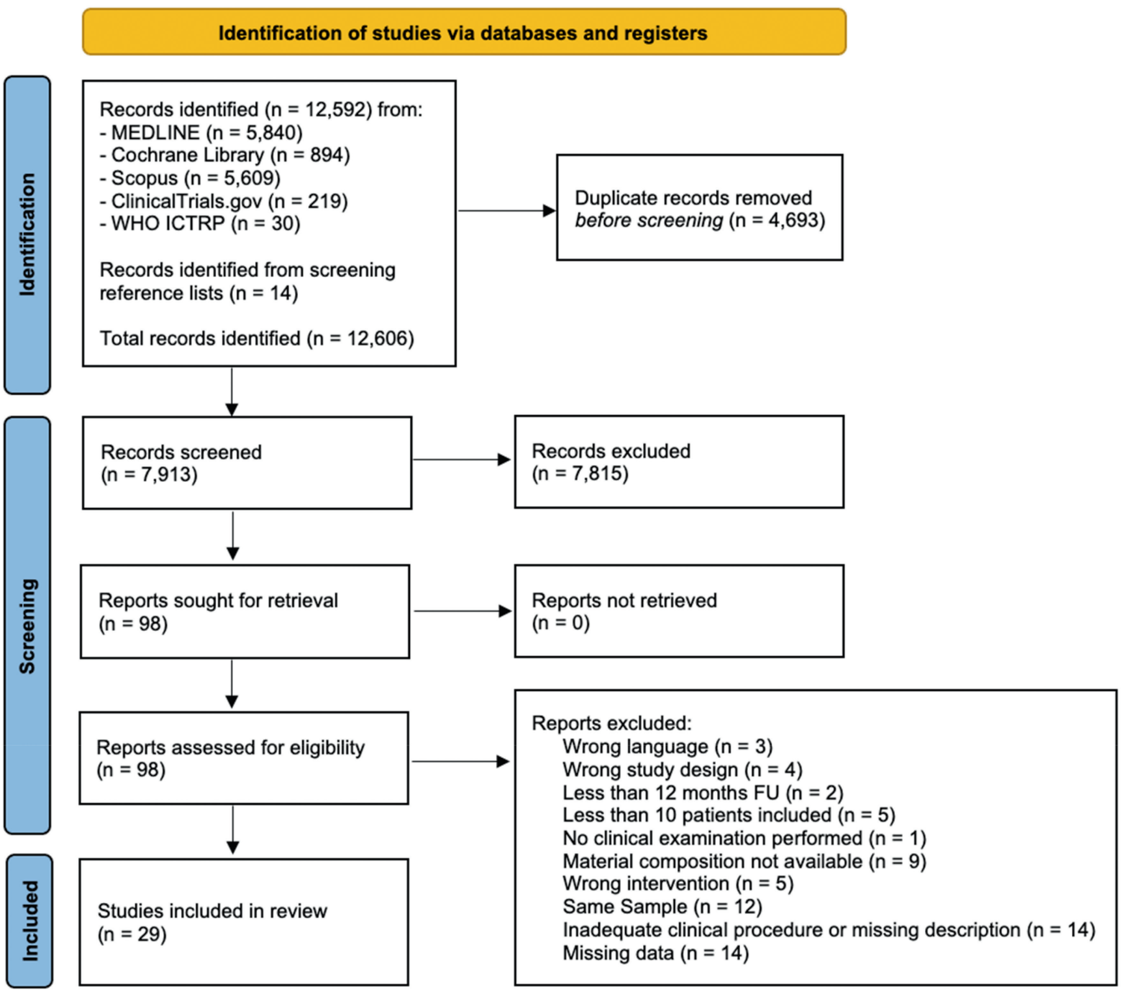


**FIGURE 1** | Prisma flow chart for article selection [20].

**TABLE 3** | Summary of included short-term studies (1–3 years); (The table presents detailed information for each study arm, with each arm listed on a separate line within the table. However, certain data points could not be specifically attributed to individual study arms and thus remain undivided across the respective cells. These undivided cells contain information that applies to the study as a whole rather than to any particular study arm).

| | Author (name first author) | Year of publication | Study type | Setting | Country | Inital number of patients | Final number of patients at FU | Dropouts | Placed number of veneers at Baseline | Follow UP mean time of FU (years) | Final number of veneers at FU | Location | | Material of restoration | Preparation | Total number of survived units | | Total number of failed units | | Vitality | Fabrication | Cementation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Number patients | | | | PM included | Jaw | | | Units | % | Units | % | | | |
| Feldspathic | De Angelis et al., 2023 [53] | 2023 | Retrospective | U | Italy | 21 | 15 | 6 | 108 | 3,59 | 78 | Yes | Maxilla | Feldspathic (IPS InLine, Ivolcar) | 1 | 76 | 97.44 | 2 | 2.56 | 1 | Conventional | Light-curing |
| | Gonzalez-Martin et al., 2021, I [57] | 2021 | Retrospective | PP | Spain | 49 | 49 | 0 | 12 | 3 | 12 | Yes | Maxilla | Feldspathic (d.sign, Ivoclar) | 4 | 12 | 100 | 0 | 0 | NR | Conventional | Light-curing |
| | Gonzalez-Martin et al., 2021, II [57] | 2021 | Retrospective | PP | Spain | | | | 125 | 3 | 125 | Yes | Maxilla | Feldspathic (d.sign, Ivoclar) | 4 | 109 | 87.2 | 16 | 12.8 | NR | Conventional | Light-curing |
| | Gonzalez-Martin et al., 2021, III [57] | 2021 | Retrospective | PP | Spain | | | | 57 | 3 | 57 | Yes | Maxilla | Feldspathic (d.sign, Ivoclar) | 1 | 54 | 94.74 | 3 | 5.26 | NR | Conventional | Light-curing |
| | Gresnigt et al., 2013 [40] | 2013 | Prospective | U | Netherlands | 20 | 20 | 0 | 92 | 1,8 | 92 | No | Maxilla | Feldspathic (Shofu Vintage AL, Shofu) | 4 | 87 | 94.57 | 5 | 5.43 | 2 | Conventional | Light-curing |
| | Nordbø et al., 1994 [46] | 1994 | Prospective | U | Norway | 41 | 41 | 0 | 135 | 3 | 135 | NR | NR | Feldspathic (nr, Ceramco) | 3 | 133 | 98.52 | 2 | 1.48 | NR | Conventional | Light-curing |
| Leucite-reinforced glass ceramic | Yildrim et al., 2023 [49] | 2023 | Prospective | U | Turkey | 11 | 11 | 0 | 30 | 2 | 30 | NR | NR | Leucite-reinforced glass ceramic (IPS Empress, Ivoclar) | 5 | 30 | 100 | 0 | 0 | 1 | Conventional | Dual-curing |
| Lithium disilicate | Fabbri et al., 2014, I [55] | 2014 | Retrospective | PP + U | Italy | NR | NR | NR | 56 | 3,46 | 56 | Yes | Both | Lithium disilicate (nr, nr) | 5 | 56 | 100 | 0 | 0 | 2 | Conventional | Both |
| | Fabbri et al., 2014, II [55] | 2014 | Retrospective | PP + U | Italy | | | | 262 | 3,46 | 262 | Yes | Both | Lithium disilicate (nr, nr) | 4 | 259 | 98.85 | 3 | 1.15 | 2 | Conventional | Both |
| | Imburgia et al., 2021 [58] | 2021 | Retrospective | PP | Italy | 105 | 105 | 0 | 893 | 2,57 | 893 | Yes | Both | Lithium disilicate (IPS e.max CAD, Ivoclar) | 4 | 892 | 99.89 | 1 | 0.11 | NR | Digital | Both |
| | Karagözoglu et al., 2016, I [43] | 2016 | Prospective | U | Turkey | 12 | 12 | 0 | 31 | 2 | 31 | Yes | Maxilla | Lithium disilicate (IPS e.max PRESS, Ivoclar) | 4 | 31 | 100 | 0 | 0 | NR | Conventional | Dual-curing |
| | Karagözoglu et al., 2016, II [43] | 2016 | Prospective | U | Turkey | | | | 31 | 2 | 31 | Yes | Maxilla | Lithium disilicate (IPS e.max PRESS, Ivoclar) | 1 | 31 | 100 | 0 | 0 | NR | Conventional | Dual-curing |
| | Malchiodi et al., 2019 [45] | 2019 | Prospective | PP + U | Italy | 13 | 13 | 0 | 79 | 3 | 79 | No | Both | Lithium disilicate (IPS e.max PRESS, Ivoclar) | 4 | 78 | 98.73 | 1 | 1.27 | NR | Conventional | Dual-curing |
| | Oztürk et al., 2014, I [47] | 2014 | Prospective | U | Turkey | 28 | 28 | 0 | 125 | 2 | 42 | No | Maxilla | Lithium disilicate (IPS e.max PRESS, Ivoclar) | 5 | 41 | 97.62 | 1 | 2.38 | 2 | Conventional | Light-curing |
| | Oztürk et al., 2014, II [47] | 2014 | Prospective | U | Turkey | | | | | 2 | 83 | No | Maxilla | Lithium disilicate (IPS e.max PRESS, Ivoclar) | 4 | 82 | 98.80 | 1 | 1.20 | 2 | Conventional | Light-curing |
| | Soares-Rusu et al., 2021, I [37] | 2021 | RCT | U | Brazil | 33 | 33 | 0 | 178 | 1 | 89 | No | Maxilla | Lithium disilicate (IPS e.max CAD, Ivoclar) | 4 | 89 | 100 | 0 | 0 | NR | Conventional | Light-curing |
| | Soares-Rusu et al., 2021, II [37] | 2021 | RCT | U | Brazil | | | 0 | | 1 | 89 | No | Maxilla | Lithium disilicate (IPS e.max PRESS, Ivoclar) | 4 | 89 | 100 | 0 | 0 | NR | Digital | Light-curing |
| | Yu et al., 2024, II [64] | 2024 | Retrospective | U | China | 56 | 51 | 5 | NR | 2,92 | 39 | Yes | Both | Lithium disilicate (IPS e.max PRESS, Ivoclar) | 3, 4 | 38 | 97.44 | 1 | 2.56 | 1 | Conventional | Dual-curing |
| | Yu et al., 2024, III [64] | 2024 | Retrospective | U | China | | | | | 2,92 | 41 | Yes | Both | Lithium disilicate (IPS e.max CAD, Ivoclar) | 3, 4 | 41 | 100 | 0 | 0 | 1 | Digital | Dual-curing |
| Zirconia | Yu et al., 2024, I [64] | 2024 | Retrospective | U | China | | | | | 2,92 | 40 | Yes | Both | 3Y-TZP zirconia (nr, Erran Tech) | 3, 4 | 40 | 100 | 0 | 0 | 1 | Digital | Dual-curing |

(Continues)

**TABLE 3** | (Continued)

| | Complications | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Technical | | | | | | | | | | Esthetic | | Biological | | | | | | | |
| | Crack | | Chipping | | Bulk fracture | | Marginal gap | | Debonding | | Marginal discoloration | | Tooth fracture | | Secondary Caries | | Endodontical complication | | Tooth loss | |
| | Units | % | Units | % | Units | % | Units | % | Units | % | Units | % | Units | % | Units | % | Units | % | Units | % |
| Feldspathic | 2 | 2.56 | 1 | 1.28 | 2 | 2.56 | 5 | 6.41 | 0 | 0 | 2 | 2.56 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | NR | NR | 0 | 0 | 0 | 0 | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR |
| | NR | NR | 15 | 12 | 1 | 0.8 | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR |
| | NR | NR | 3 | 5.26 | 0 | 0 | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR |
| | 0 | 0 | 1 | 1.09 | 3 | 3.26 | 16 | 17.39 | 1 | 1.09 | 12 | 13.04 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | NR | NR | 5 | 3.70 | 2 | 1.48 | NR | NR | NR | NR | 0 | 0 | 0 | 0 | 0 | 0 | Nr | Nr | 0 | 0 |
| Leucite-reinforced glass ceramic | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 26.67 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lithium disilicate | NR | NR | 5 | 1.57 | 0 | 0 | NE | NR | 1 | 0.31 | NE | NR | NR | NR | NR | NR | NR | NR | NR | NR |
| | NR | NR | | | 3 | 1.15 | NE | NR | | | NE | NR | NR | NR | NR | NR | NR | NR | NR | NR |
| | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0.45 | 1 | 0.11 | 1 | 0.11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 19.35 | 0 | 0 | 4 | 12.90 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 19.35 | 0 | 0 | 8 | 25.81 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | NR | NR | NR | NR | NR | NR | NR | NR | 1 | 1.27 | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR |
| | 0 | 0 | 1 | 0.8 | 0 | 0 | 0 | 0 | 1 | 2.38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 0 | 0 | | | 1 | 1.20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 0 | 0 | 0 | 0 | 0 | 0 | NR | NR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 0 | 0 | 0 | 0 | 0 | 0 | NR | NR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 0 | 0 | 0 | 0 | 1 | 2.56 | 1 | 2.56 | 0 | 0 | 0 | 0 | NR | NR | 0 | 0 | NR | NR | 0 | 0 |
| | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 9.76 | 0 | 0 | 0 | 0 | NR | NR | 0 | 0 | NR | NR | 0 | 0 |
| Zirconia | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NR | NR | 0 | 0 | NR | NR | 0 | 0 |

*Note:* Preparation 1: No-prep, 2: Window, 3: Feather, 4: Butt-joint, 5: Palatal chamfer; vitality: 1: Only vital teeth, 2: Vital and non-vital teeth.
Abbreviations: NE, not extractable; NR, not reported; PP, private practice; RCT, randomized clinical trial; U, university.

**TABLE 4** | Summary of included mid-term studies (4–6 years); (The table presents detailed information for each study arm, with each arm listed on a separate line within the table. However, certain data points could not be specifically attributed to individual study arms and thus remain undivided across the respective cells. These undivided cells contain information that applies to the study as a whole rather than to any particular study arm).

| | Author (name first author) | Year of publication | Study type | Setting | Country | Inital number of patients | Final number of patients at FU | Dropouts | Placed number of veneers at Baseline | Follow UP mean time of FU (years) | Final number of veneers at FU | Location | | Material of restoration | Preparation | Total number of survived units | | Total number of failed units | | Vitality | Fabrication | Cementation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Number patients | | | | PM included | Jaw | | | Units | % | Units | % | | | |
| Feldspathic | Faus-Matoses et al., 2020 [39] | 2020 | Prospective | U | Spain | 64 | 64 | 0 | 364 | 5.2 | 364 | Yes | Both | Feldspathic (nr, Noritake Kisai Co) | 2 | 329 | 90.38 | 35 | 9.62 | 2 | Conventional | NE |
| | Gresnigt et al., 2019 [41] | 2019 | Prospective | U | Netherlands | 118 | 104 | 14 | 444 | 4.65 | 384 | No | Maxilla | Feldspathic (Creation Zi CT, Willi Geller International) | 4 | 365 | 95.05 | 19 | 4.95 | 2 | Conventional | Light-curing |
| | Kihn et al., 1998 [44] | 1998 | Prospective | U | USA | 12 | NR | NR | 59 | 4 | 53 | NR | NR | Feldspathic (Colorlogic, Ceramco) | 2, 3, 4, 5 | 53 | 100 | 0 | 0 | NR | Conventional | Light-curing |
| | Fradeani et al., 2005, II [56] | 2005 | Retrospective | PP | Italy | 46 | 46 | 0 | 39 | 5.69 | 39 | No | Both | Feldspathic (Vitadur Alpha, Vita) | 4, 5 | 39 | 100 | 0 | 0 | 2 | Conventional | Both |
| Leucite-reinforced glass ceramic | Fradeani et al., 2005, I [56] | 2005 | Retrospective | PP | Italy | | | | 143 | 5.69 | 143 | No | Both | Leucite-reinforced glass ceramic (IPS Empress, Ivoclar) | 4, 5 | 138 | 96.50 | 5 | 3.50 | 2 | Conventional | Both |
| | Guess et al., 2014, I [42] | 2014 | Prospective | U | Germany | 25 | 9 | 14 | 42 | 6.83 | 18 | No | Both | Leucite-reinforced glass ceramic (IPS Empress, Ivoclar) | 5 | 18 | 100 | 2 | 11.11 | 1 | Conventional | Dual-curing |
| | Guess et al., 2014, II [42] | 2014 | Prospective | U | Germany | | | | 24 | 6.83 | 10 | No | Both | Leucite-reinforced glass ceramic (IPS Empress, Ivoclar) | 4 | 10 | 100 | 0 | 0 | 1 | Conventional | Dual-curing |
| | Nejatidanesh et al., 2018, I [60] | 2018 | Retrospective | PP | Iran | 71 | 71 | 0 | 92 | 5 | 92 | No | Both | Leucite-reinforced glass ceramic (IPS Empress CAD, Ivoclar) | 4 | 90 | 97.83 | 2 | 2.17 | 1 | Digital | Light-curing |
| Lithium disilicate | Nejatidanesh et al., 2018, II [60] | 2018 | Retrospective | PP | Iran | | | | 105 | 5 | 105 | No | Both | Lithium disilicate (IPS e.max CAD, Ivoclar) | 4 | 105 | 100 | 0 | 0 | 1 | Digital | Light-curing |
| | Imburgia et al., 2019 [59] | 2019 | Retrospective | PP | Italy | 53 | 53 | 0 | 258 | 4.53 | 258 | Yes | Both | Lithium disilicate (IPS Empress 2 and IPS e.max CAD, Ivoclar) | 4 | 257 | 99.61 | 1 | 0.39 | NR | Conventional | Both |
| | Yang et al., 2016 [63] | 2016 | Retrospective | U | China | NE | NE | NE | 2295 | 5 | 2295 | Yes | NR | Lithium disilicate (IPS e.max PRESS, Ivoclar) | 4 | 2242 | 97.69 | 57 | 2.48 | 2 | Conventional | Dual-curing |

(Continues)

**TABLE 4** | (Continued)

| | Complication | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Technical | | | | | | | | | | Esthetic | | Biological | | | | | | | |
| | Crack | | Chipping | | Bulk fracture | | Marginal gap | | Debonding | | Marginal discoloration | | Tooth fracture | | Secondary Caries | | Endodontical complication | | Tooth loss | |
| | Units | % | Units | % | Units | % | Units | % | Units | % | Units | % | Units | % | Units | % | Units | % | Units | % |
| Feldspathic | NR | NR | NR | NR | 28 | 7.69 | NR | NR | 7 | 72.8 | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR |
| | 14 | 3.64 | 3 | 0.78 | 15 | 3.91 | 43 | 11.2 | 3 | 0.78 | 71 | 18.49 | 3 | 0.78 | 1 | 0.26 | 0 | 0 | 1 | 0.26 |
| | 2 | 3.77 | NR | NR | 0 | 0 | 8 | 15.09 | NR | NR | 1 | 1.89 | NR | NR | 0 | 0 | 0 | 0 | NR | NR |
| | NR | NR | 0 | 0 | 0 | 0 | 14 | 7.69 | 6 | 3.30 | 24 | 13.19 | NR | NR | NR | NR | NR | NR | NR | NR |
| Leucite-reinforced glass ceramic | NR | NR | 3 | 2.10 | 2 | 1.40 | | | | | | | NR | NR | NR | NR | NR | NR | NR | NR |
| | 0 | 0 | 6 | 33.33 | 1 | 5.56 | 13 | 72.22 | 1 | 5.56 | 14 | 77.78 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 1 | 10 | 0 | 0 | 0 | 0 | 8 | 80 | 0 | 0 | 8 | 80 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | NR | NR | 3 | 3.26 | 2 | 2.17 | 8 | 8.70 | 4 | 4.35 | NR | NR | NR | NR | NR | NR | 0 | 0 | NR | NR |
| Lithium disilicate | NR | NR | 0 | 0 | 0 | 0 | 4 | 3.81 | 0 | 0 | NR | NR | NR | NR | NR | NR | 0 | 0 | NR | NR |
| | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 1.94 | 1 | 0.39 | 4 | 1.55 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 0 | 0 | 0 | 0 | 41 | 1.79 | NR | NR | 7 | 0.31 | NR | NR | NR | NR | NR | NR | 0 | 0 | NR | NR |

*Note:* Preparation 1: No-prep, 2: Window, 3: Feather, 4: Butt-joint, 5: Palatal chamfer; vitality: 1: Only vital teeth, 2: Vital and non-vital teeth.
Abbreviations: NE, not extractable; NR, not reported; PP, private practice; RCT, randomized clinical trial; U, university.

**TABLE 5** | Summary of included long-term studies (≥;7 years); (The table presents detailed information for each study arm, with each arm listed on a separate line within the table. However, certain data points could not be specifically attributed to individual study arms and thus remain undivided across the respective cells. These undivided cells contain information that applies to the study as a whole rather than to any particular study arm).

| | Author (name first author) | Year of publication | Study type | Setting | Country | Inital number of patients | Final number of patients at FU | Dropouts | Placed number of veneers at Baseline | Follow UP mean time of FU (years) | Final number of veneers at FU | Location | | Material of restoration | Preparation | Total number of survived units | | Total number of failed units | | Vitality | Fabrication | Cementation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Number patients | | | | PM included | Jaw | | | Units | % | Units | % | | | |
| Feldspathic | D'Arcangelo et al., 2012 [38] | 2012 | Prospective | U | Italy | 30 | 26 | 4 | 119 | 7 | 111 | No | Maxilla | Feldspathic (Omega 900, Vita) | 4 | 108 | 97.30 | 3 | 2.70 | 1 | Conventional | Light-curing |
| | Peumans et al., 2004 [50] | 2004 | Prospective | U | Belgium | 25 | 22 | 3 | 87 | 10 | 81 | Yes | Maxilla | Feldspathic (GC Cosmotech Porcelain, GC) | 5 | 78 | 96.30 | 3 | 3.70 | 2 | Conventional | Light-curing |
| | Pitta et al., 2024 [61] | 2024 | Retrospective | U | Switzerland | 37 | 10 | 27 | NR | 20.7 | 50 | No | Maxilla | Feldspathic (Creation, Klema) | 4, 5 | 48 | 96 | 2 | 4 | NR | Conventional | Light-curing |
| | Smielak et al., 2022, I [48] | 2022 | Prospective | U | Poland | 14 | 14 | 0 | 186 | 9.06 | 84 | Yes | Both | Feldspathic (Sakura Interaction, Elephant B.V.) | 5 | 74 | 88.10 | 10 | 11.90 | 2 | Conventional | Dual-curing |
| | Smielak et al., 2022, II [48] | 2022 | Prospective | U | Poland | 21 | 21 | 0 | | 9.06 | 102 | Yes | Both | Feldspathic (Sakura Interaction, Elephant B.V.) | 1 | 102 | 100 | 0 | 0 | 2 | Conventional | Dual-curing |
| Leucite-reinforced glass ceramic | Gresnigt et al., 2019 [36] | 2019 | RCT | U | Netherlands | 11 | 11 | 0 | 24 | 8.08 | 24 | No | Maxilla | Leucite-reinforced glass ceramic (IPS Empress Esthetic, Ivoclar) | 4 | 24 | 100 | 0 | 0 | 2 | Conventional | Light-curing |
| | Rinke et al., 2020 [62] | 2020 | Retrospective | PP | Germany | 37 | 31 | 6 | 130 | 10.81 | 101 | No | Both | Leucite-reinforced glass ceramic (Cergo, Dentsply Sirona) | 4, 5 | 91 | 90.10 | 10 | 9.90 | 1 | Conventional | Dual-curing |
| Lithium disilicate | Aslan et al., 2019 [52] | 2019 | Retrospective | U | Turkey | NR | 41 | NR | 364 | 10 | 364 | Yes | NR | Lithium disilicate (IPS e.max PRESS, Ivoclar) | 4 | 358 | 98.35 | 6 | 1.65 | NR | Conventional | Light-curing |
| | Aslan et al., 2019 [51] | 2019 | Retrospective | PP + U | Turkey | 51 | 51 | 0 | 413 | 11.33 | 413 | Yes | Both | Lithium disilicate (IPS Empress II and IPS e.max PRESS, Ivoclar) | 4 | 398 | 96.37 | 15 | 3.63 | 1 | Conventional | Light-curing |
| | Demirekin et al., 2022 [54] | 2022 | Retrospective | U | Turkey | NR | 34 | NR | 358 | 10 | 358 | Yes | Both | Lithium disilicate (IPS e.max PRESS, Ivoclar) | 5 | 342 | 95.53 | 16 | 4.47 | NR | Conventional | Light-curing |

(Continues)

**TABLE 5** | (Continued)

| | Complications | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Technical | | | | | | | | | | Esthetic | | Biological | | | | | | | |
| | Crack | | Chipping | | Bulk fracture | | Marginal gap | | Debonding | | Marginal discoloration | | Tooth fracture | | Secondary Caries | | Endodontical complication | | Tooth loss | |
| | Units | % | Units | % | Units | % | Units | % | Units | % | Units | % | Units | % | Units | % | Units | % | Units | % |
| Feldspathic | 7 | 6.31 | 8 | 7.21 | 0 | 0 | 3 | 2.70 | 0 | 0 | 5 | 4.50 | 0 | 0 | 1 | 0.90 | 2 | 1.80 | 0 | 0 |
| | 17 | 20.99 | 2 | 2.47 | 9 | 11.11 | 76 | 93.83 | 0 | 0 | 52 | 64.20 | NR | NR | 16 | 19.75 | 3 | 3.70 | 0 | 0 |
| | 3 | 6 | 9 | 18 | 2 | 4 | 16 | 32 | 1 | 2 | 34 | 68 | NR | NR | 6 | 12 | 0 | 0 | 0 | 0 |
| | 1 | 1.19 | 3 | 3.57 | 7 | 8.33 | 0 | 0 | 5 | 5.95 | 1 | 1.19 | 1 | 1.19 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2 | 1.96 | 2 | 1.96 | 2 | 1.96 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.98 | 0 | 0 | 0 | 0 |
| Leucite-reinforced glass ceramic | 1 | 4.17 | 0 | 0 | 0 | 0 | 10 | 41.67 | 0 | 0 | 7 | 29.17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 0 | 0 | 1 | 0.99 | 8 | 7.92 | 0 | 0 | 9 | 8.91 | 10 | 9.90 | 0 | 0 | 2 | 1.98 | 2 | 1.98 | 1 | 0.99 |
| Lithium disilicate | NR | NR | NR | NR | 2 | 0.55 | NR | NR | 4 | 1.10 | 0 | 0 | 0 | 0 | NR | NR | NR | NR | NR | NR |
| | NR | NR | 6 | 1.45 | 0 | 0 | 53 | 12.83 | 9 | 2.18 | 48 | 11.62 | NR | NR | 0 | 0 | 2 | 0.48 | 0 | 0 |
| | 1 | 0.28 | 3 | 0.84 | 1 | 0.28 | 0 | 0 | 8 | 2.23 | 0 | 0 | NR | NR | 3 | 0.84 | 0 | 0 | 0 | 0 |

*Note:* Preparation 1: No-prep, 2: Window, 3: Feather, 4: Butt-joint, 5: Palatal chamfer; vitality: 1: Only vital teeth, 2: Vital and non-vital teeth.
Abbreviations: NR, not reported; PP, private practice; RCT, randomized clinical trial; U, university.

52, 54, 57–59, 61] and none of the included studies reported solely of laminate veneers on endodontically treated abutment teeth. All of the ceramic laminate veneers were adhesively cemented. Twenty-one study arms reported on light-cured resin cementation [36–38, 40, 41, 44, 46, 47, 50–52, 54, 57, 60, 61], 13 on dual-cured resin bonding [42, 43, 45, 48, 49, 62–64], six [55, 56, 58, 59] on both light- and dual-cured bonded ceramic laminate veneers and one study [39] did not mention their adhesive bonding protocol.

## 3.3 | Risk of Bias Assessment

In general, all included clinical studies showed some concern being not completely bias free. Studies were rated with a low to moderate risk of bias (Figures 2 and 3). Regarding publication bias, funnel plots and Eggers-test for pooled survival rates for short- ($p = 0.520$), mid- ($p = 0.675$) and long-term ($p = 0.685$) follow-up showed no clear signs for asymmetry. However, it was not possible to explore the potential of publication bias using funnel plots for further subgroup analyses due to a low number of available studies.

## 3.4 | Survival Rates

Meta-analyses were performed for short- (1–3 years), mid- (4–6 years) and long-term (≥ 7 years) follow-up (Figures 4–6). According to the proposed time ranges, studies and their corresponding populations were judged by the authors as sufficiently similar to perform a meta-analysis.

### 3.4.1 | Short-Term Laminate Veneer Survival (1–3 Years)

Twelve studies with 20 study arms reported on the performance of 2304 ceramic laminate veneers with a mean follow-up of 2.6 years [37, 40, 43, 45–47, 49, 53, 55, 57, 58, 64] (Table 3, Figure 4). The meta-analysis revealed a pooled survival rate of 97.76% (95% CI: 96.42%–99.01%) for all ceramic laminate veneers in the short-term, with a high statistical heterogeneity between studies ($I^2 = 72.03\%$). When pooling the survival rates by different ceramic material class, the following results were obtained: 94.86% (95% CI: 90.14%–97.84%) for feldspathic ceramics ($I^2 = 67.82\%$, based on 499 laminate veneers) [40, 46, 53, 57], 100% for LRGC (based on 30 laminate veneers) [49], 99.21% (95% CI: 98.58%–99.66%) for LDS ($I^2 = 19.23\%$, based on 1735 laminate veneers) [37, 43, 45, 47, 55, 58, 64] and 100% for zirconia (based von 40 laminate veneer restorations) [64]. A statistical comparison of the pooled survival rates for feldspathic porcelain versus LDS laminate veneers suggests a slightly higher survival rate for LDS laminate veneers ($p < 0.01$).

### 3.4.2 | Mid-Term Laminate Veneer Survival (4–6 Years)

Eight studies with 11 study arms evaluated the performance of ceramic laminate veneers being 4–6 years in function (Table 4, Figure 5) [39, 41, 42, 44, 56, 59, 60, 63]. No studies were available for zirconia laminate veneers. A pooled survival rate of 97.12% (95% CI: 95.22%–98.79%) at a mean follow-up of 5.0 years for 3761 laminate veneers could be plotted with substantial statistical heterogeneity between clinical trials ($I^2 = 81.69\%$). Feldspathic laminate veneers showed a pooled survival rate of 95.68% (95% CI: 91.27%–98.61%) ($I^2 = 80.28\%$, based on 840 restorations) [39, 41, 44, 56] and LDS a pooled survival rate of 98.8% (95% CI: 97.13%–99.76%) ($I^2 = 74.55\%$, based on 2658 laminate veneers) [59, 60, 63], with LDS laminate veneers showing again slightly higher pooled survival rates than feldspathic laminate veneers ($p = 0.048$). LRGC laminate veneers showed a pooled survival rate of 96.95% (95% CI: 94.48%–98.73%) ($I^2 = 0\%$, based on 263 laminate veneers) [42, 56, 60]. No difference was found for pooled survival rates of feldspathic laminate veneers compared to LRGC laminate veneers ($p = 0.574$) and LRGC laminate veneers with LDS laminate veneers ($p = 0.121$).

### 3.4.3 | Long-Term Laminate Veneer Survival (≥ 7 Years)

Nine studies with 10 study arms were included in the long-term evaluation of ceramic laminate veneers [36, 38, 48, 50–52, 54, 61, 62]. No studies were available for zirconia laminate veneers. The pooled survival rate for 1688 laminate veneers was 96.05% (95% CI: 93.87%–97.46%) at a mean follow-up period of 10.4 years ($I^2 = 69.07\%$) (Table 5, Figure 6). Pooled survival rates by different ceramic materials were: feldspathic 96.13% (95% CI: 91.32%–98.89%) ($I^2 = 74.61\%$, based on 428 laminate veneers) [38, 48, 50, 61], LRGC 93.7% (95% CI: 82.82%–99.75%) ($I^2 = 61.01\%$, based on 125 laminate veneers) [36, 62] and LDS 96.81% (95% CI: 94.81%–98.34%) ($I^2 = 62.29\%$, based on 1135 laminate veneers) [51, 52, 54]. No difference was found comparing the pooled survival rates of feldspathic and LRGC laminate veneers ($p = 0.582$),

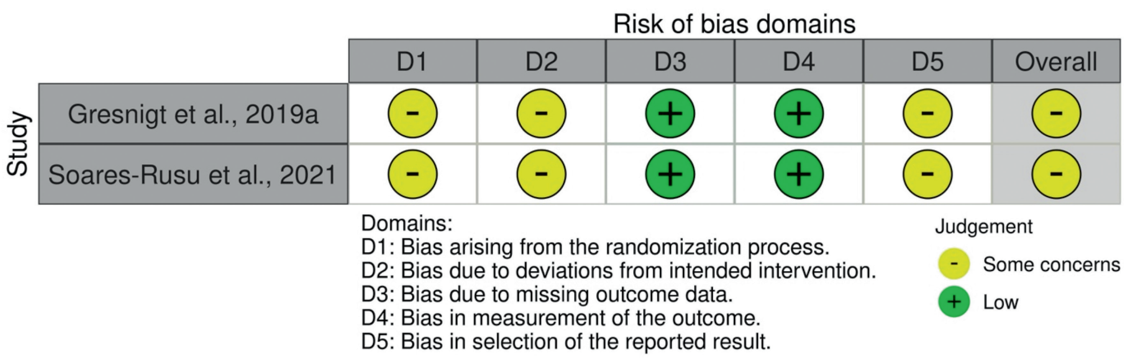


**FIGURE 2** | Risk of bias assessment summary according the Revised Cochrane risk-of-bias tool for randomized trials (Rob2) [30].

| | Aslan et al., 2019a | Aslan et al., 2019b | D'Arcangelo et al., 2012 | De Angelis et al., 2023 | Demirekin et al., 2022 | Fabbri et al., 2014 | Faus-Matoses et al., 2020 | Fradeani et al., 2005 | Gonzalez-Martin et al., 2021 | Gresnigt et al., 2013 | Gresnigt et al., 2019b | Guess et al., 2014 | Imburgia et al., 2021 | Imburgia et al., 2019 | Karagözoglu et al., 2016 | Kihn et al., 1998 | Malchiodi et al., 2019 | Nejatidanesh et al., 2018 | Nordbø et al., 1994 | Öztürk et al., 2014 | Peumans et al., 2004 | Pitta et al., 2024 | Rinke et al., 2020 | Smielak et al., 2022 | Yang et al., 2016 | Yildrim et al., 2023 | Yu et al., 2024 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. A clearly stated aim: | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 2. Inclusion of consecutive patients: | 2 | 0 | 0 | 2 | 2 | 2 | 2 | 0 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 2 | 2 | 1 | 2 | 0 | 2 | 2 | 2 | 2 | 2 | 2 |
| 3. Prospective collection of data: | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 4. Endpoints appropriate to the aim of the study: | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 5. Unbiased assessment of the study endpoint: | 0 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 2 | 1 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 |
| 6. Follow-up period appropriate to the aim of the study: | 2 | 2 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| 7. Loss to follow up less than 5%: | 0 | 2 | 1 | 1 | 2 | 0 | 2 | 2 | 2 | 2 | 1 | 0 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 2 | 0 | 2 | 2 |
| 8. Prospective calculation of the study size: | 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 |
| **TOTAL MINOR SCORE** | 10 | 12 | 11 | 11 | 13 | 10 | 12 | 10 | 13 | 13 | 12 | 11 | 12 | 10 | 11 | 11 | 11 | 13 | 11 | 13 | 11 | 12 | 12 | 14 | 10 | 13 | 13 |

**FIGURE 3** | Risk of bias assessment summary according to the methodological index for non-randomized studies (MINORS) [29].

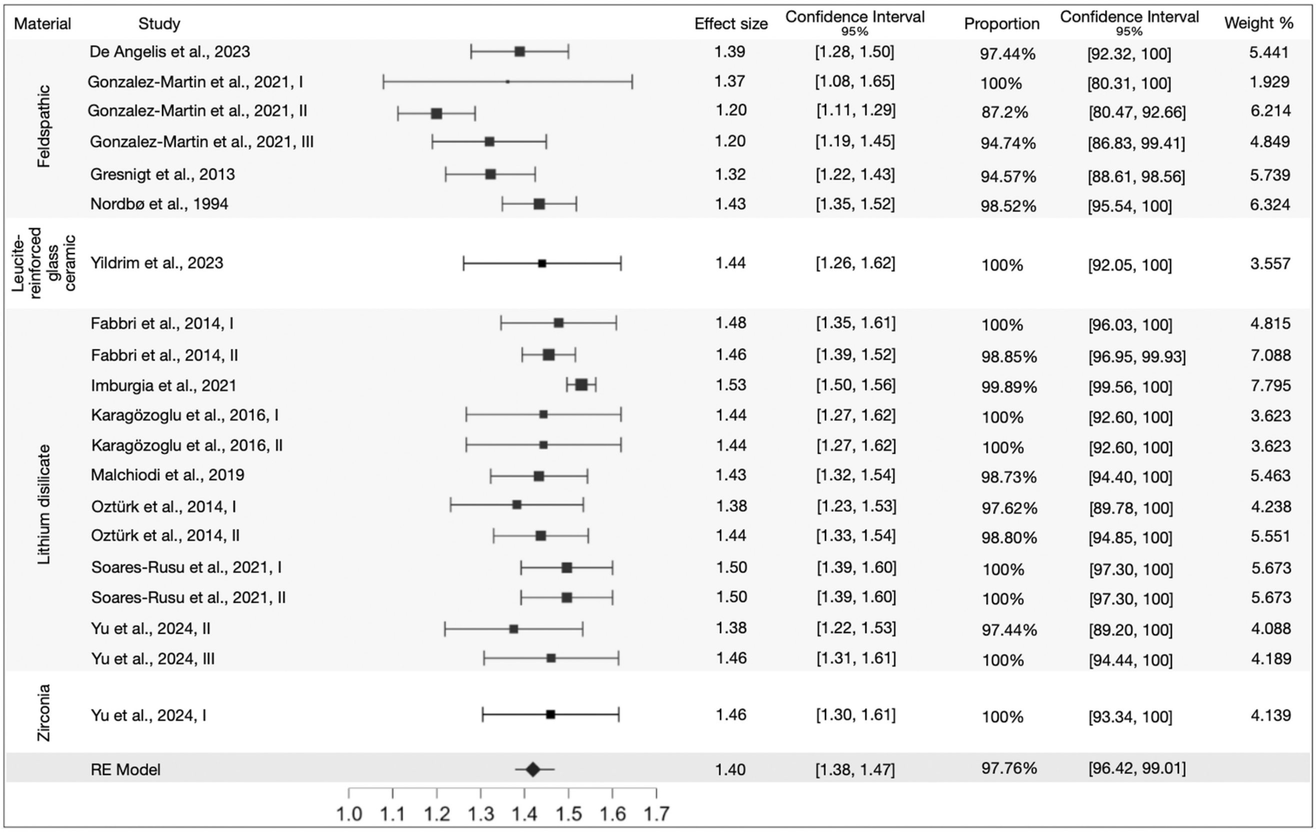


**FIGURE 4** | Forrest plot on the outcome of short-term survival (1–3 years). (Random Effects model: DerSimonian-Laird method. Heterogeneity: $\tau^2 = 0.002$, $I^2 = 72.027\%$, $H^2 = 3.575$).

feldspathic and LDS laminate veneers ($p = 0.667$) and for LRGC versus LDS laminate veneers ($p = 0.104$).

## 3.5 | Technical Complications

Meta-analysis revealed a pooled technical complication rate of 6.59% (95% CI: 3.55%–10.48%) ($I^2 = 89.20\%$, based on 101 incidences out of 2304 laminate veneers at risk) [37, 40, 43, 45–47, 49, 53, 55, 57, 58, 64] in the short-term. The complications rates accounted for: 11.04% for feldspathic laminate veneers (95% CI: 6.03%–17.31%) ($I^2 = 73.56\%$, 57 incidences out of 499 laminate veneers) [40, 46, 53, 57], 26.67% for LRGC laminate veneers (8 incidences out of 30 laminate veneers) [49], 3.92% for LDS (95% CI: 1.65%–7.09%) ($I^2 = 82.77\%$, 36 events out of 1735 restorations) [37, 43, 45, 47, 55, 58, 64] and 0% for zirconia at a mean follow-up of 2.6 years [64]. LDS laminate veneers showed slightly less technical complications than feldspathic laminate veneers in the short-term ($p = 0.018$).

Mid-term meta-analysis yielded a pooled technical complication rate of 16.62% (95% CI: 8.72%–26.43%) ($I^2 = 97.01\%$,

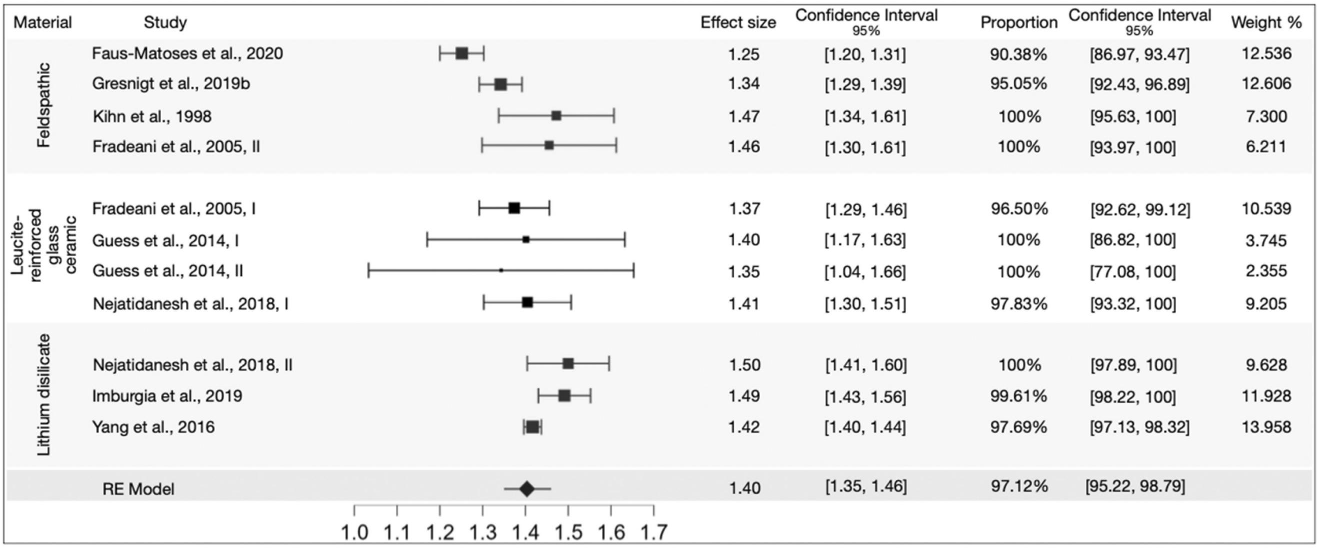


**FIGURE 5** | Forrest plot on the outcome of mid-term survival (4–6 years). (Random Effects model: DerSimonian-Laird method. Heterogeneity: $\tau^2 = 0.005$, $I^2 = 81.691\%$, $H^2 = 5.462$).

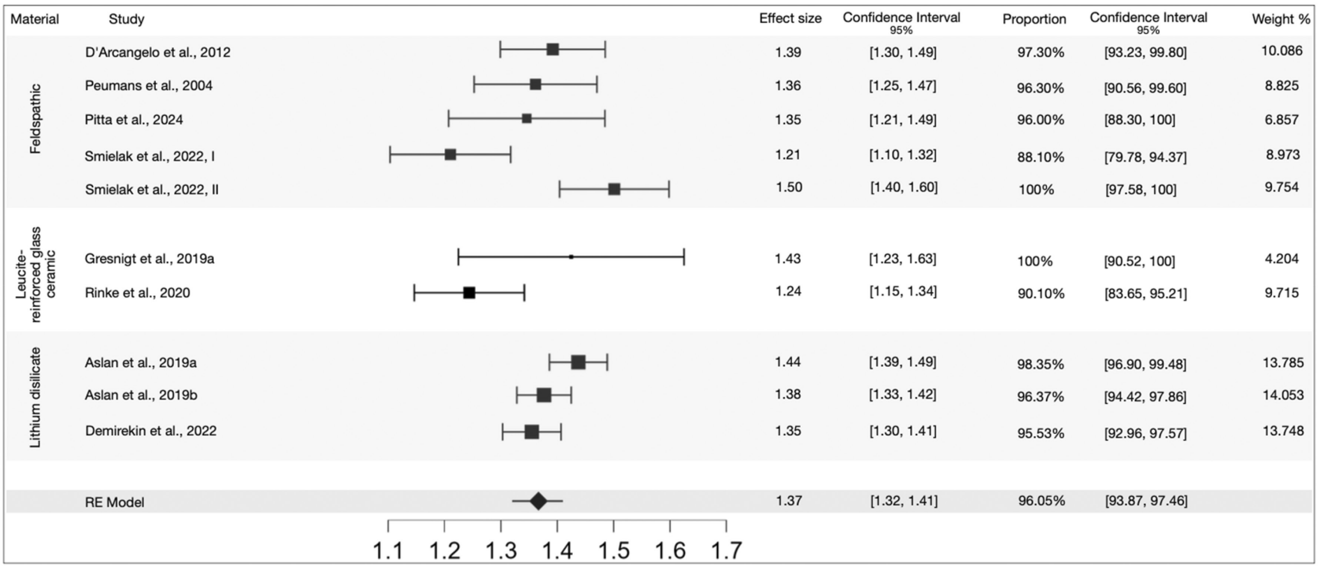


**FIGURE 6** | Forrest plot on the outcome of long-term survival (> 7 years). (Random Effects model: DerSimonian-Laird method. Heterogeneity: $\tau^2 = 0.004$, $I^2 = 69.077\%$, $H^2 = 3.234$).

253 incidences with 3761 laminate veneers at risk) [39, 41, 42, 44, 56, 59, 60, 63]. According to the type of ceramic material, the technical complication rates were: 11.71% for feldspathic (95% CI: 5.14%–20.48%) ($I^2 = 90.00\%$, 123/840) [39, 41, 44, 56], 50.46% for LRGC (95% CI: 10.97%–89.61%) ($I^2 = 97.54\%$, 52/263) [42, 56, 60] and 2.22% for LDS (95% CI: 1.66%–2.84%) ($I^2 = 0\%$, 58/2658) [59, 60, 63]. LDS laminate veneers showed slightly less technical complications than feldspathic ($p = 0.004$) and LRGC laminate veneers ($p < 0.001$) in the mid-term. No difference was detected between feldspathic and LRGC laminate veneers ($p = 0.021$).

Meta-analysis for long-term evaluation of pooled technical complications resulted in 26.42% (95% CI: 10.48%–46.46%) ($I^2 = 98.55$, 291 events out of 1688 laminate veneers at risk) [36, 38, 48, 50–52, 54, 61, 62] at a mean follow-up of 10.4 years. Regarding technical complications distributed by ceramic material class the meta-analysis calculated a pooled rate of 41.48% for feldspathic porcelain (95% CI 6.51%–83.39%) ($I^2 = 98.83\%$, 175/428) [38, 48, 50, 61], 29.87% for LRGC (95% CI: 7.3%–59.48%) ($I^2 = 86.18\%$, 29/125) [36, 62] and 6.1% for LDS (95% CI: 0.60%–16.60%) ($I^2 = 97.18\%$, 87/1135) [51, 52, 54]. LDS laminate veneers were less prone to technical complications compared to feldspathic porcelain ($p = 0.044$) and LRGC laminate veneers ($p = 0.033$). No difference was found for technical complications comparing feldspathic porcelain and LRGC laminate veneers ($p = 0.778$). Detailed meta-analysis for long-term technical complications relating to specific events showed a pooled rate of 4.3% for crack formation (95% CI: 1.15%–9.26%) ($I^2 = 87.78\%$, 32/911), 3.53% for chipping events (95% CI: 1.64%–5.62%) ($I^2 = 74.34\%$, 34/1324), 2.51% for bulk fractures (95% CI: 0.97%–5.17%) ($I^2 = 85.45\%$, 31/1688), 13.73%

for marginal gap formation (95% CI: 1.91%–32.8%) ($I^2 = 98.50\%$, 158/1324) and 2.2% for debonding (95% CI: 1.18%–3.54%) ($I^2 = 62.02\%$, 36/1688).

### 3.6 | Esthetic Complication Rates

In the short-term, meta-analysis revealed a pooled esthetic complication rate of 2.51% (95% CI: 0.78%–5.17%) ($I^2 = 83.35\%$, based on 27 events in 1713 laminate veneers under risk). A detailed distribution of esthetic complications by ceramic material yielded in the following rates: 3.8% for feldspathic porcelain (95% CI: 0%–14.34%) ($I^2 = 90.77\%$, based on 14 incidences in 305 laminate veneers) [40, 53], 2.2% for LDS (95% CI: 0.45%–5.62%) ($I^2 = 81.69\%$, 13 events in 1338 laminate veneers) [43, 58] and 0% both for LRGC (0 events in 30 laminate veneers) [49] and zirconia (0 events in 40 laminate veneers) [64] based on one study each. No statistically significant difference was identified for the pooled esthetic complication rates of feldspathic porcelain and LDS ($p = 0.590$). At a mean follow-up of 5.0 years, the esthetic complication rate increased to 22.96% (95% CI: 9.26%–39.53%) ($I^2 = 96.08\%$, 122 events in 905 laminate veneers) [41, 42, 44, 56, 59], whereas it decreased to 12.39% (95% CI: 3.54%–25.54%) at a mean follow-up of 10.4 years ($I^2 = 97.89\%$, 157 incidences in 1688 laminate veneers at risk) [36, 38, 48, 50–52, 54, 61, 62]. No further subgroup analyses were possible for mid-term follow-up. LDS as a restoration material for ceramic laminate veneers showed an esthetic complication rate of 1.9% (95% CI: 0.45%–11.72%) ($I^2 = 98.05\%$, 48 incidences in 1135 laminate veneers) [51, 52, 54], whereas felspathic ceramics comprised a rate of 19.64% (95% CI: 0.88%–54.46%) ($I^2 = 98.31\%$, 92 out of 428) [38, 48, 50, 61] and LRGC a rate of 17.89% (95% CI: 3.19%–39.45%) ($I^2 = 79.91\%$, 17 out of 125) [36, 62] in the long-term follow-up. Comparisons of esthetic complications between different ceramics revealed no advantage in favor of one of the materials (feldspathic vs. LRGC $p = 0.972$, feldspathic vs. LDS $p = 0.117$ and LRGC vs. LDS $p = 0.087$).

### 3.7 | Biological Complication Rates

No biological complications were reported in the short-term. In the mid-term one study reported about one incident of secondary caries (0.26%) and one abutment tooth loss (0.26%) [41]. No meta-analysis was performed. In studies with a mean follow-up of more than 7 years, one tooth fracture (1.19%) [48] and one tooth loss (0.99%) [62] were reported in two studies. A meta-analysis for biological complications yielded in a pooled rate of 3.18% (95% CI: 1.18%–6.58%) ($I^2 = 88.96\%$, based on 40 events out of 1688 laminate veneers) at 10.4 years. Detailed meta-analysis revealed the following pooled biological complication rates for the long-term follow-up: 6.51% for feldspathic laminate veneers (95% CI: 1.09%–15.81%) ($I^2 = 89.46\%$, based on 30 events out of 428 laminate veneers) [38, 48, 50, 61], 4.4% for LRGC laminate veneers (95%CI: 1.29%–8.40%) ($I^2 = 0\%$, based on 5 out of 125 laminate veneers) [36, 62] and 0.45% for LDS laminate veneers (95% CI: 0.12%–1.16%) ($I^2 = 30.29\%$, based on 5 events out of 1135 laminate veneers) [51, 52, 54]. Comparisons between ceramic materials resulted in slightly less biological complications for LDS versus feldspathic laminate veneers ($p = 0.010$) and for LDS versus LRGC laminate veneers ($p = 0.003$). No difference was found between feldspathic and LRGC laminate veneers ($p = 0.651$). Additionally, a meta-analysis was performed for the occurrence of secondary caries with a pooled complication rate of 2.83% (95% CI: 0.77%–6.09%) ($I^2 = 87.60\%$, based on 29 events out of 1324 laminate veneers) [36, 38, 48, 50, 51, 54, 61, 62] and for endodontical complications with a pooled rate of 0.96% (95% CI: 0.32%–1.91%) ($I^2 = 36.97\%$, based on nine reported incidences out of 1324 laminate veneers) [36, 38, 48, 50, 51, 54, 61, 62] at a mean follow-up of 10.4 years.

## 4 | Discussion

Ceramic laminate veneers showed a pooled survival rate of 97.76% (95% CI: 96.42%–99.01%) in the short-term, 97.12% (95% CI: 95.22%–98.79%) at 5.0 years and 96.05% (95% CI: 93.87%–97.46%) at 10.4 years of follow-up, showing favorable results across all time points. The meta-analysis of the long-term evaluation of different ceramic materials yielded in 96.13% for feldspathic porcelain (95% CI: 91.32%–98.89%) [38, 48, 50, 61], 93.7% for LRGC (95% CI: 82.82%–99.75%) [36, 62] and 96.81% for LDS (95% CI: 94.81%–98.34%) [51, 52, 54] at 10.4 years. No statistically significant difference was found comparing the survival rates and no long-term studies were available for zirconia. However, at 10.4 years, LDS slightly outperformed both feldspathic and LRGC laminate veneers in terms of pooled technical and biological complications. No difference was found for pooled esthetic complications between different ceramic materials at long-term follow-up. Further subgroup analyses for single criterions for both technical and biological complications subdivided by ceramic material class were not possible due to the insufficient number of events and studies at 10.4 years.

Therefore, ceramic laminate veneers can be considered as a reliable and minimally invasive treatment option for the rehabilitation of anterior teeth. These findings are consistent with a recently published systematic review, which reported an estimated 10-year cumulative survival rate of 95.5%, based on 6500 laminate veneer restorations [14]. Lower survival rates of 89% (based on 2848 laminate veneers) after a median follow-up time of 9 years have also been observed [15]. Both reviews differ from the present one, since they did not compare different ceramic materials including LDS and zirconia, nor did they separately evaluate survival and complication rates across several time points [14, 15]. One of the reviews described lower survival rates of 87% for feldspathic laminate veneers (based on 1283 laminate veneers) at 8 years and 94% for LRGC (based on 676 laminate veneers) at 7 years [15]. In contrast to the present review, the most frequently observed complication was fracture (4%), which typically occurred in the first few years after insertion, followed by debonding (2%), marginal discoloration (2%), endodontic problems (2%) and secondary caries (1%) [14, 15].

In this review it seems that in short-term, esthetic and biological complications can be neglected for all types of ceramic materials. The most frequently observed technical complications at 2.6 years included, chipping (25 events) [40, 46, 53, 57] and marginal gap formation (21 events) [40, 53] for feldspathic laminate veneers, marginal gap (8 events) [49] for LRGC and marginal gap (21 events) [43, 58, 64] and chipping for LDS (6 events)

[47, 55]. At mid-term follow-up of 5.0 years biological complications rarely occurred, however, technical and esthetical complications increased over time. Feldspathic laminate veneers seem to be most susceptible to marginal discoloration (72 events) [41, 44], marginal gap formation (51 events) [41, 44] and bulk fracture (43 events) [39, 41], LRGC to marginal gap (29 events) [42, 60], marginal discoloration (22 events) [42] and chipping (12 events) [42, 56, 60] and LDS to bulk fracture (41 events) [63] and marginal gap formation (9 events) [59, 60].

At 10.4 years, the most prevalent complications were: marginal gap formation (95 events) [38, 50, 61] and marginal discoloration (92 events) [38, 48, 50, 61] for feldspathic porcelain, marginal discoloration (17 events) and marginal gap (10 events) [36, 62] for LRGC and marginal gap (53 events) [51] and marginal discoloration (48 events) [51] for LDS. A possible explanation for the high occurrence of marginal gap formation and marginal discoloration might be that gingival recessions were noted over time, leading to exposed margins and leakage of the adhesive interface [50, 51, 61]. Nevertheless, laminate veneers were rarely replaced due to marginal gap formation or discoloration [50, 51, 61]. Other technical complications, such as cracks (4.3%) and chipping (3.53%) occurred less frequently at 10.4 years. The same applies to the criteria of secondary caries (2.83%) and endodontic complications (0.96%). LDS was overall slightly less susceptible to technical and biological complications, which can be attributed to its superior mechanical properties [6, 7]. The mechanical supremacy of LDS can be related to two key mechanisms: elongated LDS crystals that form an interlocking crystal pattern that limits crack propagation and the mismatch between the LDS-glass coefficient of thermal expansion (CTE) that creates compressive stresses around the crystals [6, 65]. Although feldspathic and LRGC laminate veneers exhibited more frequent complications than LDS, biological failures were rarely observed and technical complications were addressed mostly without restoration replacement. Failures requiring a new restoration, such as bulk fractures (2.51%) and debondings (2.2%) were also seldomly encountered at long-term follow-up. A recently published review reported 5-year survival rates of 96.4% for all-ceramic anterior single crowns and 96.9% for anterior partial coverage restorations [27]. Biological complications (caries, endodontic and periodontal problems, root fracture) were 50% higher for single crowns than for partial-coverage restorations in the anterior region owing to a more aggressive preparation design for full-coverage restorations [27]. The influence of preparation design, fabrication method (conventional vs. CAD/CAM) and the choice of adhesive resin cement could not be analyzed due to heterogenous study data. With respect to preparation design and bonding substrate, almost all of the studies tried to preserve as much enamel as possible during preparation to guarantee a strong adhesive bond [7, 51, 54, 55, 57, 58, 60]. Seven out of the 29 studies reported that the laminate veneers were solely bonded to enamel [39, 43–46, 49, 53]. Ceramic laminate veneers, which were bonded to larger areas of dentin were more likely to cause complications over time and thus identified as a potential risk factor for failures [45, 48, 54, 60]. Other systematic reviews concluded that incisal overlapping and bonding to enamel, especially at margins, led to lower failure rates compared non-overlapping and bonding to dentin and existing restorations [14, 20]. Focusing on additional potential risk factors for failures, it is noteworthy that eight studies did not explicitly excluded patients with parafunctional habits [36, 38–41, 48, 55, 58]. Most of these studies implemented occlusal guards post-cementation as a protective measure to patients with parafunctions [36, 38–41, 48, 58]. One study observed a twofold increase in risk of laminate veneer fracture in patients with bruxism compared to those without [39]. Furthermore, in bruxism patients, the risk of fracture was seven times higher for those not wearing a splint than for those who wore one [39]. Occlusal guards as a protective measure might therefore be beneficial to reduce the risk of laminate veneer fracture, especially in patients with parafunctional habits. Moreover, the studies which analyzed overall patient experience could generally note an increase of patient satisfaction before and after ceramic laminate veneer treatment [37, 41, 50, 51, 55, 60, 61, 64].

To the authors best knowledge this is the first systematic review on ceramic laminate veneers, which grouped clinical studies in short- (1–3 years), mid- (4–6 years), and long-term (≥ 7 years) follow-up and differentiated between survival and associated complication rates across different study periods and different ceramic materials, including zirconia. Therefore, this review offers valuable insights into the performance of these restorations analyzing the most recent literature.

However, the findings should be interpreted with caution due to several limitations. In the absence of RCTs comparing different types of ceramic materials, only prospective and mostly retrospective studies with limited sample sizes were available for meta-analysis. Moreover, wide clinical and methodological variations including different definitions of survival and failures among individual studies were observed, largely due to the lack of standardized reporting across studies, resulting in an overall high heterogeneity $I^2$ in the meta-analysis. Although more recent studies have attempted to adhere to the currently recognized FDI criteria [66] and reporting standards, such as the CONSORT [67], TREND [68] and STROBE [69] statements, consistent adherence was not possible, given the variation in publication dates from 1994 to 2024. Another factor which was under-reported in most of the studies, but can contribute to the longevity of laminate veneer restorations are recall intervals as well as special instructions for maintenance care and protective measures (e.g., nightguards). As a result, the comparison and meta-analytic modeling of pooled results, with sometimes small sample sizes in subgroup analyses, exhibited high heterogeneity across studies, undermining precise estimation of pooled effect sizes and their differences. Therefore, only general tendencies rather than robust conclusions can be drawn.

Future clinical studies should be ideally designed as RCTs and should explore not only direct comparisons of different ceramic materials but also digital CAD/CAM workflows. While most digitally manufactured laminate veneers are currently produced using subtractive methods, recent in vitro studies have shown promising results with additively fabricated 3D-printed ceramic laminate veneers, featuring thin layers and high accuracy [25]. Moreover, none of the existing studies have evaluated monolithic versus layered laminate veneers or reported on RMCs and lithium silicate ceramics. As only one study investigated monolithic 3 mol% yttria-stabilized tetragonal zirconia (3Y-TZP) laminate veneers bonded with an universal adhesive and a dual-curing resin cement [64], future research could further explore the potential of zirconia as a restorative material for laminate veneers with its different generations and translucencies. In times of patient-centered dental care, future studies should also evaluate and analyze patient and clinician reported outcome measurements (PROMs/CROMs) in addition to survival and complications rates.

The key results of this systematic review indicate that feldspathic, LRGC and LDS reveal high survival rates across all investigated time periods and can be recommended for long-term clinical use. Zirconia seems to be a promising restorative alternative for laminate veneers in the short-term. Nevertheless, when selecting a restorative material for ceramic laminate veneers clinicians should consider potential complications that may arise over time and affect the longevity of the restoration.

## 5 | Conclusion

Ceramic laminate veneers fabricated out of feldspathic, leucite-reinforced glass ceramic and lithium disilicate ceramic are a minimally invasive and reliable treatment option with favorable long-term results. Lithium disilicate ceramic slightly outperforms feldspathic and leucite-reinforced glass ceramic laminate veneers in terms of technical and biological complications. The long-term performance of zirconia laminate veneers remains uncertain.

**Conflicts of Interest**

The authors declare no conflicts of interest.

**Data Availability Statement**

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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**Supporting Information**

Additional supporting information can be found online in the Supporting Information section.