# A Systematic Review and Meta-Analysis of the Survival of Feldspathic Porcelain Veneers Over 5 and 10 Years

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***Purpose:*** This systematic review reports on the survival of feldspathic porcelain veneers. ***Materials and Methods:*** The Cochrane Library, MEDLINE (OVID), Embase, Web of Knowledge, selected journals, clinical trials registers, and conference proceedings were searched independently by two reviewers. Academic colleagues were also contacted to identify relevant research. Inclusion criteria were human cohort studies (prospective and retrospective) and controlled trials assessing outcomes of feldspathic porcelain veneers in more than 15 patients and with at least some of the veneers in situ for 5 years. Of 4,294 articles identified, 116 studies underwent full-text screenings and 69 were further reviewed for eligibility. Of these, 11 were included in the qualitative analysis and 6 (5 cohorts) were included in meta-analyses. Estimated cumulative survival and standard error for each study were assessed and used for meta-, sensitivity, and post hoc analyses. The $I^2$ statistic and the Cochran Q test and its associated *P* value were used to evaluate statistical heterogeneity, with a random-effects meta-analysis used when the *P* value for heterogeneity was less than .1. Galbraith, forest, and funnel plots explored heterogeneity, publication patterns, and small study biases. ***Results:*** The estimated cumulative survival for feldspathic porcelain veneers was 95.7% (95% confidence interval [CI]: 92.9% to 98.4%) at 5 years and ranged from 64% to 95% at 10 years across three studies. A post hoc meta-analysis indicated that the 10-year best estimate may approach 95.6% (95% CI: 93.8% to 97.5%). High levels of statistical heterogeneity were found. ***Conclusions:*** When bonded to enamel substrate, feldspathic porcelain veneers have a very high 10-year survival rate that may approach 95%. Clinical heterogeneity is associated with differences in reported survival rates. Use of clinically relevant survival definitions and careful reporting of tooth characteristics, censorship, clustering, and precise results in future research would improve meta-analytic estimates and aid treatment decisions. *Int J Prosthodont 2012;25:590–603.*

Laminate veneers have been used since the 1930s to improve the appearance of teeth, but the porcelain veneering technique did not enter mainstream dentistry until the 1980s, when enamel etching and porcelain surface treatments improved the predictability of bonding.

The incidence of veneer treatment in general dentistry and specialist prosthodontic services has been infrequently reported in the scientific literature. In 2009, Burke and Lucarotti[1] and Lucarotti et al[2] reported that porcelain veneers accounted for 2,562 of 503,965 treatments (0.5%) in 82,537 patients over 11 years in the general dental services in England and Wales. In 2007, Layton and Walton[3] reported that porcelain veneers accounted for 304 of 5,712 treatments (1.7%) in 945 patients over 16 years in a specialist prosthodontic referral clinic in Australia. Despite this low frequency, the availability of these veneers is regularly highlighted in popular magazines and television programs.

The clinical outcomes of porcelain veneers have been reported, but the results remain contradictory. Reported 10-year failure rates of feldspathic veneers have ranged from 5%[4] to 47%,[1] while 5-year failure rates have ranged from 2%[4] to 42%.[5] The most recent systematic review of porcelain veneer outcomes was conducted by Kreulen et al in 1998.[6] That study included 10 articles on porcelain veneers with follow-up times between 2 and 5.25 years; the estimated survival after 3 years was 92% (95% confidence interval [CI]: 90% to 94%).

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In recent years, an increased number of ceramic materials have become available for veneer treatment, with the outcomes of each material supported by literature of varying degrees of scientific rigor. These supposedly new-and-improved materials are marketed not only to dentists but also directly to the public. In a commentary in 2009, Friedman[7] lamented the bittersweet silver anniversary of the veneer, stating that "the economic incentives associated with the porcelain veneer 'industry' have spawned disturbing trends, misleading information, and an unprecedented level of overtreatment in our profession." An improved understanding of the clinical outcomes of these restorations would clearly be of benefit.

This systematic review reports and discusses the survival of feldspathic porcelain veneers. This study is part of a research project that aimed to systematically identify and appraise the outcomes of laminate veneers constructed from various materials. The review aimed to *(1)* identify all relevant studies, whether or not they had been published, that followed at least some of the veneers for 5 years; *(2)* calculate the best possible overall summary survival estimate; *(3)* examine sources of study heterogeneity that may impact this estimate; and *(4)* explore possible biases in research methods that may impact this estimate.

## Materials and Methods

### *Article Identification*

The Cochrane Library (as of June 2011), MEDLINE (OVID, 1950 to June 2011), Embase (1980 to June 2011), and Web of Knowledge (1856 to June 2011) were searched using a combination of keywords and index terms (medical subject headings [MeSH] for MEDLINE and Emtree for Embase). Keywords included "porcelain and veneer*" OR "dental and veneer*" OR "laminate* and veneer*" OR "porcelain and laminate*" OR "dental and laminate*"; MeSH and Emtree included "DENTAL VENEERS." No formal limits or other constraints were used. An example search is outlined in Table 1.

The following journals were hand-searched from January 2005 to June 2011: *Evidence-Based Dentistry*, *International Journal of Prosthodontics*, *Journal of Prosthetic Dentistry*, *Journal of Adhesive Dentistry*, *Journal of Esthetic and Restorative Dentistry,* and *Journal of Oral Rehabilitation*. References of identified articles were examined for relevant studies.[8]

Clinical trials registers, conference proceedings, and contacts with academic colleagues were used to identify unpublished data, abstracts, and other gray literature. Articles in languages other than English were identified and translated. Article identification, screening, and eligibility and inclusion assessments were completed independently by two reviewers. Disagreement was resolved by discussion. The measure of agreement between the two reviewers (kappa statistic) was reported for the screening process.

**Table 1** Example search for MEDLINE (OVID) database

| |
|---|
| (porcelain and veneer*) OR |
| (dental and veneer*) OR |
| (laminate* and veneer*) OR |
| (porcelain and laminate*) OR |
| (dental and laminate*) OR |
| [DENTAL VENEERS] |

* = truncation of keywords; ( ) = keyword; [ ] = medical subject heading.

Figure 1 shows a flowchart of the search process. Inclusion criteria included human prospective and retrospective cohort and controlled trials assessing the outcome of feldspathic porcelain veneers in more than 15 patients. At least some of the veneers in each study had to be in situ for 5 years. In vitro, laboratory, review, and opinion articles were excluded. Veneers placed using unusual techniques, such as with no enamel preparation or excessive incisal edge lengthening, were excluded. Care was taken to ensure that any cohorts reported more than once were not counted twice; if a study had been reported more than once, the most complete reporting of the relevant population was considered for inclusion. Authors of studies with incomplete data were contacted to facilitate inclusion of their studies in the meta-analysis.

Of the 4,294 articles identified, screening of titles and abstracts by two independent reviewers identified 116 studies for full-text review (kappa = 0.85, indicating excellent agreement). Of these 116 studies, 69 clinical trials investigating dental laminate veneers were identified. No randomized trials were identified. The full-text reports led to the exclusion of articles because they were studies of nonporcelain (n = 12) or non-feldspathic porcelain (n = 17) restorations, did not report porcelain type (n = 4), or followed feldspathic porcelain veneers for less than 5 years (n = 20).

Of the remaining 16 studies, 5 were excluded: 2 contained previously reported data,[3,9] 1 assessed outcomes of veneers on unprepared enamel surfaces,[5] and 2 assessed outcomes of veneers with extreme incisal edge lengthening.[10,11]

Of the remaining 11 studies, 4[1,12–14] did not report sufficient data to facilitate meta-analysis, and it was not possible to obtain the necessary data from the

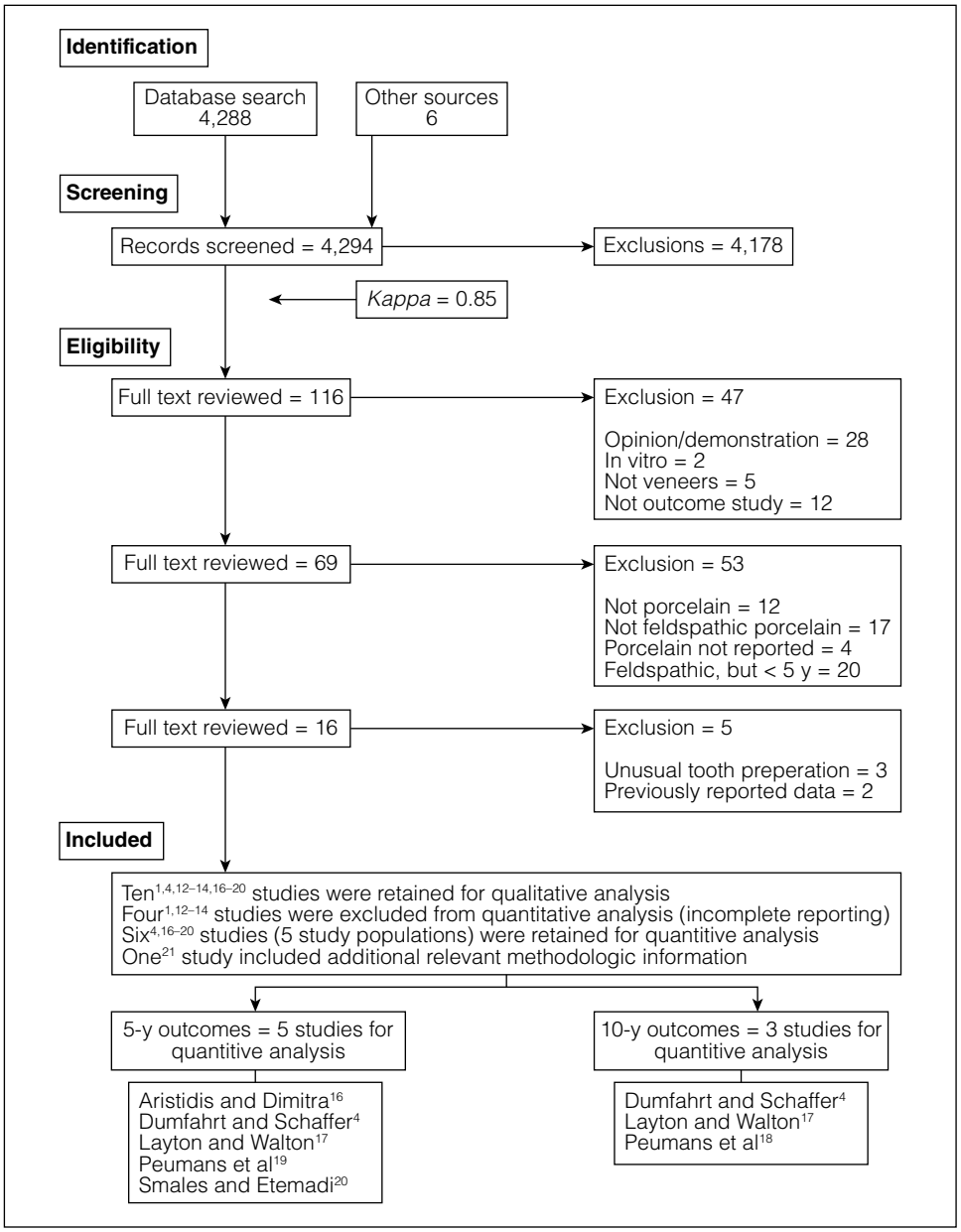



**Fig 1** Flowchart of the search process.

original researchers. Specifically, these articles did not directly report on or provide sufficient information to extract outcomes of feldspathic veneers only,[14] estimated Kaplan-Meier survival,[13] or associated standard error.[1] Another article followed veneers for up to 5.25 years but ceased reporting at 4 years due to concerns regarding increased statistical uncertainty.[12] These studies were retained for the qualitative discussion but excluded from quantitative analysis.

Overall, six[4,15–19] studies regarding five different study populations were retained for meta-analysis. One[20] study with additional relevant methodologic information was retained. Data for some patient populations were distributed across multiple articles.[4,17,18,20]

### *Articles Included in the Meta-analysis*

Of the six studies included in the meta-analysis, two[4,19] were retrospective cohorts and four[15–18] were prospective cohorts. The number of patients ranged from 50 to 155 with a median of 61, while the number of veneers ranged from 87 to 499 with a median of 186. A rough

average showed that patients received between 1.6 and 5.8 veneers each. For one study,[17] the outcomes were assessed both per veneer and per patient. For five studies, the outcomes were assessed per veneer only; therefore, clustered outcomes may have biased the estimated cumulative survival. The effect of clustered outcomes is further explored in the discussion. The study characteristics are summarized in Table 2.

All six studies reported veneer outcome as survival; however, each study defined survival differently. For consistency, data were extracted and the outcome redefined according to the six-field criteria[21]: success, survival, dead, lost to follow-up, repaired, or failed (Table 3). A failed veneer was defined as one that required an intervention that disrupted the original marginal integrity (eg, restoration to manage caries), was partially or completely lost for any reason (eg, large fracture, tooth extraction), or lost retention more than twice. Deaths and losses to follow-up were considered censored data. Successful, surviving, and repaired veneers were classified as "survivals" for reporting purposes.

Of the six studies, 5-year survival estimates were provided by five studies, three of which also provided 10-year survival estimates. When possible, the estimated cumulative survival and 95% CI were extracted for both 5 and 10 years. Individual participant data were available only for one of the six studies; therefore, outcomes could not be changed to per patient in most of the studies and had to be kept as per veneer.

Suitable summary data were available directly from the texts of Smales and Etemadi[19] (5-year survival = 96% [95% CI: 86% to 105%]) and Peumans et al[17,18] (5-year survival = 92% [95% CI: 90% to 94%]; 10-year survival = 64% [(95% CI: 51% to 77%]) with appropriately defined outcome measures.

The individual participant data of Layton and Walton[16] were available to facilitate data extraction. The study reported the 20-year estimated cumulative survival, which was analyzed in two ways: per veneer (Table 2) and per patient. For consistency, outcomes reported per veneer rather than per patient were included in the meta-analysis (5-year survival = 98% [95% CI: 96% to 100%]; 10-year survival = 96% [95% CI: 92% to 100%]). With access to the individual patient data, the 20-year outcomes could be retrospectively divided into up to 10-year outcomes for two different patient cohorts, facilitating sensitivity analysis. Group 1 included 88 patients with 239 veneers (10-year survival = 96% [95% CI: 94% to 99%]) who received treatment between 1990 and 2000, and group 2 included 260 veneers in 67 patients (10-year survival = 95% [95% CI: 90% to 99%]) who received treatment between 2001 and 2010.

Suitable summary data were not directly available for the remaining two studies[4,15] but could be estimated using other information reported by the authors. Aristidis and Dimitra[15] reported the data qualitatively, while Dumfahrt and Schaffer[4] reported the cumulative estimated survival without a standard error or confidence interval. For both studies, the following data with appropriately defined outcome measures were extracted: number of veneers in situ, number censored, number failed, and timing of these outcomes. Life tables were constructed with yearly intervals. The estimated cumulative survival was calculated using the Kaplan-Meier[22] method, and the standard error was calculated with the Greenwood formula.

For Aristidis and Dimitra,[15] the data were reported qualitatively in text and tables, allowing extraction, construction of life tables, and re-analysis. The 5-year cumulative survival was estimated to be 95% (95% CI: 91% to 98%).

For Dumfahrt and Schaffer,[4,20] the data were extracted from both the text and graphs for recalculation. The graphs were reproduced and scaled to allow the timing of failures and censoring to be read, life tables were reconstructed, and the standard error was calculated. The recalculated estimated cumulative survival at both 5 and 10 years differed from that reported in the text. The recalculated survival rate was 95% at 10 years (originally reported survival = 91%) and 98% at 5 years (originally reported survival = 97%). The distribution (but not the absolute value) of the events and censoring was read from the graph provided by the authors. When the discrepancy was noted, the events were redistributed and the calculations revised to investigate the effect of extraction error. No redistribution altered the estimated probability by more than 1%, with the lowest calculated for 10 years being 94%. It was concluded that the original authors' estimates for cumulative survival may have been based on assumptions not commonly incorporated into Kaplan-Meier analysis. The higher cumulative survival and associated standard error recalculated for this study were used for further analysis and are reported in Table 2.

### *Articles Included in the Qualitative Discussion*

Of the four studies included in the qualitative discussion but not the quantitative analyses, three[1,13,14] were retrospective cohorts and one[12] was a prospective cohort. The number of patients ranged from 29 to 1,177 with a median of 96, while the number of veneers ranged from 62 to 2,562 with a median of 1,438.5. A rough average showed that patients

**Table 2** Articles Retained for Quantitative and Qualitative Analysis

| Author | Design/sample |
|---|---|
| Aristidis and Dimitra (2002)[15] | Prospective cohort<br>Follow-up: 5 y<br>Inclusion period: 1993–1998<br>Language: English<br>Sample: 186 veneers, 61 patients (age range: 18 to 70 y), mean = 3.1 veneers/patient* |
| Dumfahrt and Schaffer (2000)[4,20] | Retrospective cohort<br>Follow-up: 10.6 y<br>Inclusion period: 1987–1997<br>Language: English<br>Sample: 205 veneers, 72 patients (age range: 13 to 63 y), mean = 2.9 veneers/patient* |
| Layton and Walton (2012)[16] | Prospective cohort<br>Follow-up: 21 y<br>Inclusion period: 1990–2010<br>Language: English<br>Sample: 499 veneers, 155 patients (mean age: 41 ± 14.1 y; range: 15 to 73 y),<br>mean = 5.8 ± 4.3 veneers/patient |
| Peumans et al (1998)[18]<br>Peumans et al (2004)[17] | Prospective cohort<br>Follow-up: 10 y<br>Inclusion period: 1990–2000<br>Language: English<br>Sample: 87 veneers, 54 patients (age range: 19 to 69 y), mean = 1.6 veneers/patient* |
| Smales and Etemadi (2004)[19] | Retrospective cohort<br>Follow-up: 7 y<br>Inclusion period: 1989–1993<br>Language: English<br>Sample: 110 veneers, 50 patients (older adolescents and adults), mean = 2.2 veneers/patient* |

CI = confidence interval.
*Mean not reported by authors and was estimated post hoc. This simple average likely underestimates the true number.

**Table 3** Six-Field Classification System[21]

| Field | Definition |
|---|---|
| **Successful** | Review of documentation or patient examination revealed no evidence of retreatment other than maintenance procedures (eg, professional prophylaxis and smoothening of minor porcelain chipping). Smoothening was considered minor when the veneer did not require further repair, the chip did not interfere with the marginal integrity, and the result did not compromise the esthetics as determined by the patient. |
| **Surviving** | Patient was not able to be examined by the author, but either the referring dentist or patient confirmed that there had been no retreatment other than that previously described for a successful outcome. |
| **Unknown** | Patient could not be located. |
| **Dead** | Any patients who died during the survey period, regardless of whether they had experienced successful or surviving treatment until their death. However, if previous documentation indicated some form of retreatment had been undertaken before death, the relevant treatment episode was categorized as having a "retreatment" outcome. |
| **Retreatment** | Patient underwent any form of retreatment other than maintenance procedures as previously described. Occlusal or lingual perforation of a tooth for access to perform endodontic therapy was not considered retreatment. This category was further subdivided to describe the result of the retreatment. |
| Repaired | Original marginal integrity of the restorations and teeth was maintained. |
| Failed | Part or all of the prosthesis was lost, the original marginal integrity of the restorations and teeth was modified, or the restoration lost retention more than once. |

received between 2.1 and 3.1 veneers each. The study characteristics are summarized in Table 4.

Burke and Lucarotti[1] retrospectively reviewed the outcomes of veneers provided to patients under the general dental services in England and Wales. They reported an up to 10-year estimated cumulative survival rate of 53%. No information was provided regarding the timing of veneer placement, veneer failures, or loss to follow-up, nor was information provided regarding the type of veneer preparation, whether enamel was prepared, or whether substantial dentin was exposed. Therefore, the standard error and 95% CI could not be extracted or estimated reliably, and the clinical characteristics that may have contributed

| Characteristics | Kaplan-Meier estimated cumulative survival (95% CI) |
|---|---|
| Setting: 1 operator, university, Greece<br>Exclusion: signs of excessive occlusal forces<br>Preparation design: 0.5-mm incisal reduction<br>Material: feldspathic porcelain with 15% aluminum oxide (Ceramco) | 5 y: 94% (91% to 98%) |
| Setting: 2 operators, university, Austria<br>Exclusion: less than 50% enamel, compromised substrate (dentinogenesis and amelogenesis imperfecta)<br>Preparation design: incisal reduction dictated by clinical requirements<br>Material: feldspathic porcelain (Optec HSP) | 5 y: 98% (96% to 100%)<br>10 y: 95% (91% to 98%) |
| Setting: 1 operator, private specialist practice, Australia<br>Exclusion: less than 80% enamel, loss of more than 1/3 incisal edge width, subjective assessment of high parafunctional risk<br>Preparation design: incisal overlap (1 to 2 mm)<br>Material: feldspathic porcelain (Mirage)<br>Outcome: reported two ways (per veneer and per patient) | 5 y: 98% (96% to 100%)<br>10 y: 96% (92% to 100%)<br>15 y: 91% (87% to 95%)<br>20 y: 91% (87% to 95%) |
| Setting: 1 operator, location not reported (authors were from Belgium)<br>Exclusion: poor oral hygiene, unfavorable occlusion, less than 50% enamel<br>Preparation design: 1- to 2-mm incisal edge reduction with shoulder prepared over a distance of 2 to 3 mm<br>Material: feldspathic porcelain (GC Cosmotech) | 5 y: 92% (90% to 94%)<br>10 y: 64% (51% to 77%) |
| Setting: 2 operators, private specialist practice, Australia<br>Exclusion: severe tooth discoloration, inadequate sound enamel, evidence of marked parafunction<br>Preparation design: incisal reduction dictated by clinical requirements<br>Material: feldspathic porcelain (Mirage) | 5 y: 96% (86% to 105%)<br>7 y: 96% (86% to 105%) |

to the clinical outcome could not be explored. The authors were contacted but were unable to provide further details.

The prospective study by Dunne and Millar[12] included 550 veneers in 170 patients, with 315 veneers in 96 patients available for review. The patients were treated by undergraduate students, house officers, and teaching staff at two dental hospitals in England. Outcomes were followed for up to 5.25 years, but the authors ceased reporting at 4 years because of concerns regarding data instability. The 4-year estimated cumulative survival rate was 73%. Insufficient data were reported to estimate the 5-year survival rate or associated standard error.

Murphy et al[14] invited 58 patients who had received veneers placed by undergraduate students at the University Dental School and Hospital, Cork, Ireland, to participate in a retrospective study. Twenty-nine patients with 62 veneers that had been in situ for up to 5 years were reviewed, with 11% having experienced a complication (6% required rebonding and 5% fractured). Veneers were fabricated by a number of laboratories from a number of different materials, including feldspathic porcelain. Unfortunately, the authors could not provide further details to allow outcomes of different veneer materials to be isolated, nor could they provide details regarding losses to follow-up. Therefore, Kaplan-Meier survival rates could not be calculated.

Friedman[13] retrospectively reviewed the failure patterns of 3,255 veneers that had been in situ for up to 15 years. Of these restorations, 93% were classified as successful, but not all patients were able to return for review. "Success" was not clearly defined. Losses to follow-up were not reported in sufficient detail to allow the calculation of Kaplan-Meier survival rates or standard error.

Although these studies could not be included in the meta-analysis, they still provide clinicians with valuable information regarding clinical outcomes.

### *Data Analysis*

The estimated cumulative survival and standard error at 5 and 10 years for each study was considered for meta-analysis. The Cochran Q test and associated *P* value were used to evaluate heterogeneity between the estimated cumulative survival rates. This test has low power to detect homogeneity.[23] For this systematic review, it was decided that a *P* value less than .1 should be regarded as suggestive of the presence of heterogeneity; in such instances, a random-effects

**Table 4** Articles Retained for Qualitative Analysis

| Study | Design/sample |
|---|---|
| Dunne and Millar (1993)[12] | Prospective cohort<br>Follow-up: 5.25 y<br>Inclusion period: 1986–1991<br>Language: English<br>Sample: 315 veneers, 96 patients (from 170 patients; mean age: 33 ± 14 y; range: 14 to 64 y), mean = 3.1 veneers/patient* |
| Burke and Lucarotti (2009)[1] | Retrospective cohort<br>Follow-up: 11 y<br>Inclusion period: 1991–2001<br>Language: English<br>Sample: 2,562 veneers, 1,177 patients (age: > 18 y), mean = 2.2 veneers/patient* |
| Murphy et al (2005)[14] | Retrospective cohort<br>Follow-up: 5 y<br>Inclusion period: 1996–2001<br>Language: English<br>Sample: 62 veneers, 29 patients (from 58 patients; age range: 20 to 69 y), mean = 2.1 veneers/patient* |
| Friedman (1998)[13] | Retrospective cohort<br>Follow-up: 15 y<br>Inclusion period: not reported<br>Language: English<br>Sample: 3,255 veneers, unknown no. of patients (age also not reported) |

*Mean not reported by authors and was estimated post hoc. This simple average likely underestimates the true number.
†Kaplan-Meier estimated cumulative survival.
‡Results reported as percentage outcomes; time-to-event analysis (eg, Kaplan-Meier) was not performed.

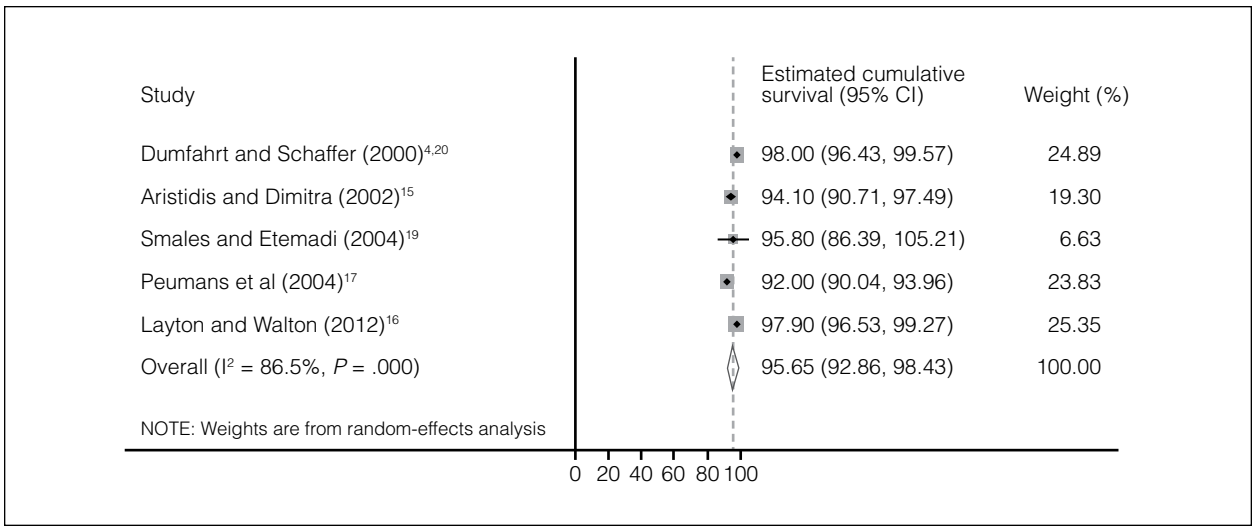



**Fig 2** Forest plot of the 5-year estimated cumulative survival of feldspathic porcelain veneers. The random-effects pooled estimate was 95.7% (95% CI: 92.9% to 98.4%) (Cochran Q = 29.71, *df* = 4, *P* < .001, $I^2$ = 86%).

meta-analysis was used to calculate the pooled summary estimate and 95% CI. The influence of fixed effects versus random effects on the calculated outcomes is explored further in the discussion. The $I^2$ statistic was calculated to evaluate variation in the summary estimate, which may be attributable to underlying heterogeneity, and a Galbraith plot was constructed to view the heterogeneity graphically.

Sensitivity analysis was performed to test the effect of underlying assumptions on the overall estimate. The influence of individual studies was assessed. The effect of the inclusion of the 20-year data reported by Layton and Walton[16] as two separate 10-year groups was investigated. The summary estimate was calculated with both the fixed- and random-effects methods, and the robustness of the results was compared.

| Characteristics | Results |
|---|---|
| Setting: undergraduate students, house officers, and teaching staff, 2 dental hospitals, England<br>Preparation design: beveled incisal edge, window, or incisal overlap<br>Exclusion: inadequate posterior support, poor oral hygiene, excessive attrition, marked evidence of previous parafunctional activity | 4 y: 73%[†] |
| Setting: general dentists in the general dental services, England and Wales<br>Preparation design: not described<br>Inclusion: random selection by birth date of adults who received at least 1 direct restoration and 1 veneer | 10 y: 53%[†] |
| Setting: undergraduate student operators, university, Ireland<br>Preparation design: not described<br>Inclusion: patients who had received veneers<br>Materials: multiple materials, including feldspathic porcelain | 11% experienced a complication (6% debonded, 5% fractured)[‡] |
| Setting: 1 operator<br>Preparation design: not described<br>Inclusion: patients who returned for review | 93% "successful"[‡] |

A funnel plot was constructed to investigate the possibility of publication bias or other biases associated with small studies. The Stata version 11 statistical package (StataCorp) was used.

## Results

### *Five-Year Results*

The 5-year summary estimates of survival ranged from 92% to 98% in the included studies. These results were statistically heterogenous (Cochran Q = 29.71, *df* = 4, *P* < .001). The random-effects method calculated a 5-year pooled cumulative survival of 95.7% (95% CI: 92.9% to 98.4%) (Fig 2). Eighty-six percent of the variance in the summary estimate was attributable to heterogeneity. The Galbraith plot (Fig 3) showed that one study[18] lay outside the CI of the plotted statistic.

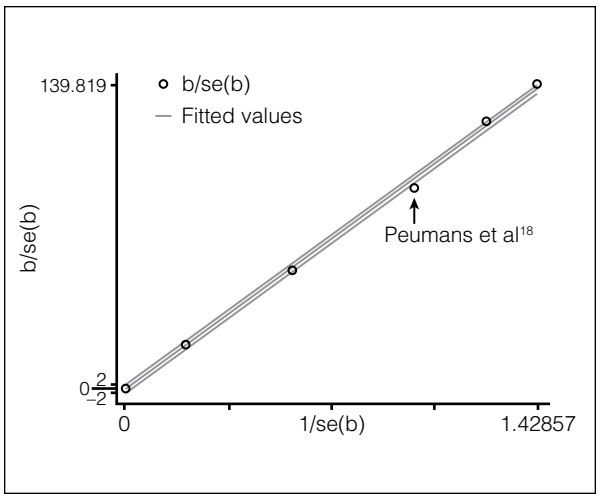
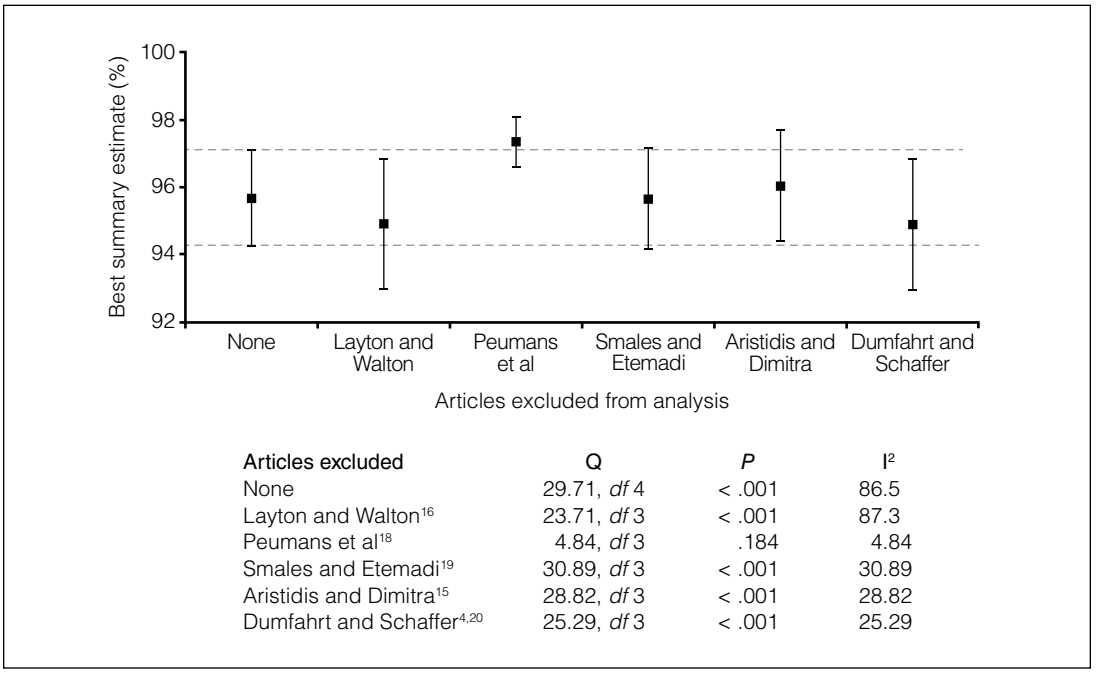



**Fig 3** Galbraith plot showing the 5-year summary log cumulative survival included as a solid line banded by its 95% CI. One study (Peumans et al[18]) lies outside the CI of the plotted statistic.

The sensitivity analysis reassessed the best summary estimate by successively removing a single study from the calculation (Fig 4). Removal of four studies individually did not alter the best estimate beyond the standard error of the original calculation or the presence of statistical heterogeneity. Removal of one study[18] increased the best summary estimate to 97.3% (95% CI: 95.9% to 98.8%), which was beyond the standard error of the original calculation. Removal of that study also decreased the presence of statistical heterogeneity (Cochran Q = 4.84, *df* = 3, *P* = .194), and the $I^2$ statistic fell from 86% with this study included to 30% without it.

The funnel plot (Fig 5) showed that studies were moderately well distributed around the point estimate, with a single large study[18] below the expected range. This suggests that the heterogeneity of the summary estimate was unlikely to be caused by publication




| Articles excluded | Q | *P* | $I^2$ |
|---|---|---|---|
| None | 29.71, *df* 4 | < .001 | 86.5 |
| Layton and Walton[16] | 23.71, *df* 3 | < .001 | 87.3 |
| Peumans et al[18] | 4.84, *df* 3 | .184 | 4.84 |
| Smales and Etemadi[19] | 30.89, *df* 3 | < .001 | 30.89 |
| Aristidis and Dimitra[15] | 28.82, *df* 3 | < .001 | 28.82 |
| Dumfahrt and Schaffer[4,20] | 25.29, *df* 3 | < .001 | 25.29 |

**Fig 4** Sensitivity analysis: 5-year results. Removal of one study (Peumans et al[18]) increased the best summary estimate to 97.3% (95% CI: 95.9% to 98.8%), which is beyond the standard error of the original calculation, and decreased statistical heterogeneity (Cochran Q = 4.84, *df* = 3, *P* = .194, $I^2$ = 30%).

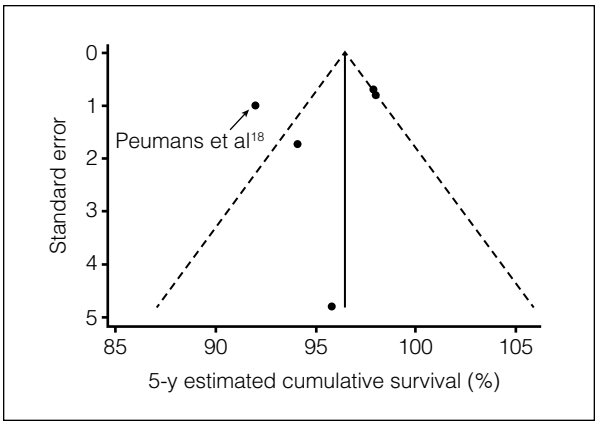



**Fig 5** Funnel plot. Studies were moderately well distributed around the point estimate.

bias (or other biases of small studies) for the 5-year estimated cumulative survival rate; however, there were too few studies to support a robust assessment of these biases.

### *Ten-Year Results*

The 10-year summary estimates of survival ranged from 64% to 96% in the included studies. These results were statistically heterogenous (Cochran Q = 23.84, *df* = 3, *P* < .001), and 87.4% of the variance of the pooled summary estimate was attributable to heterogeneity. Figure 6 shows a forest plot of the results. This very high level of heterogeneity meant that pooling through meta-analysis was not justified. The Galbraith plot (Fig 7) showed that one study[17] lay outside the CI of the plotted statistic. This heterogeneity was also evident in the forest plot, with the CIs around the point estimate for Peumans et al[17] separate from those of the other two studies.

Sensitivity analysis revealed that removal of Peumans et al[17] decreased the statistical heterogeneity (Cochran Q = 0.62, *df* = 2, *P* = .733), and the $I^2$ statistic fell from 90% to 0% when this study was removed from the meta-analysis. Post hoc removal of this study and inclusion of three study estimates (Dumfahrt and Schaffer[4] and groups 1 and 2 of Layton and Walton[16]) resulted in a 10-year pooled estimated cumulative survival rate of 95.6% (95% CI: 93.8% to 97.5%) (Fig 8).

## Discussion

The summary estimate for cumulative survival at 5 and 10 years showed marked statistical heterogeneity, which is evident from the Cochran Q test and associated *P* value, $I^2$ statistic, and distribution of summary estimates on the forest plot and Galbraith plot. The Cochran Q test assesses whether there is

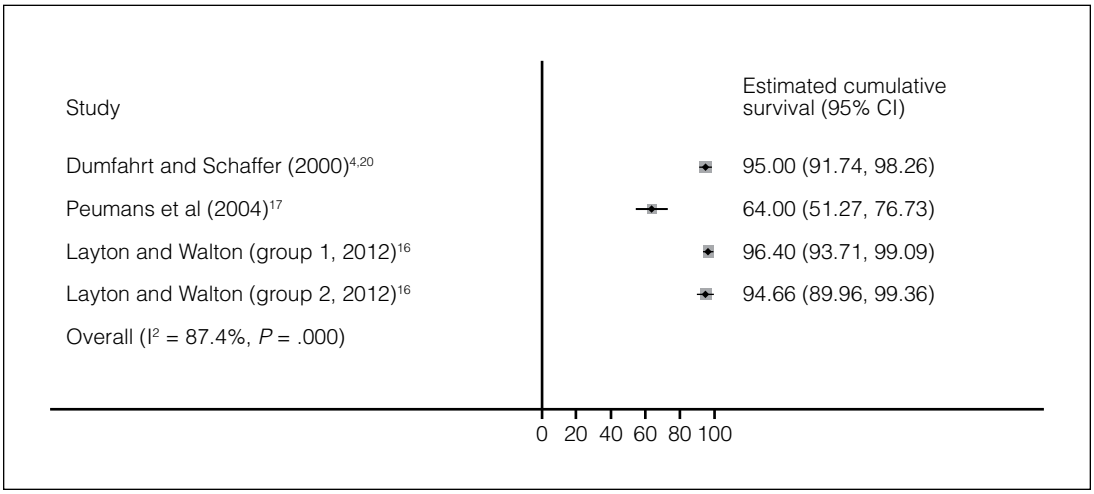



**Fig 6** Forest plot of the 10-year estimated cumulative survival of feldspathic porcelain veneers. Marked heterogeneity was found between studies (Cochran Q = 23.84, *df* = 3, *P* < .001, $I^2$ = 87.4%). The summary estimate was not pooled.

greater variation between the trial results than would be expected by random chance. This statistical test has low power, especially when there is a smaller number of studies, and may fail to detect a lack of homogeneity even when present.[23] For this meta-analysis, however, *P* values of < .001 were calculated at both 5 and 10 years; thus, heterogeneity was clearly present. The $I^2$ statistic indicated that the variance in the summary estimate attributable to heterogeneity was 86% for the 5-year results and 90% for the 10-year results. Although the calculated summary estimates are mathematically correct, this statistical heterogeneity shows that these estimates are unlikely to be clinically reliable and that the outcomes are not consistent across different settings.

The forest plot of the 5-year data shows the survival outcomes (ranging from 92% to 98%) and their associated CIs. The estimated cumulative failure rate over 5 years ranged from 2% to 8%, a fourfold difference. A Galbraith plot was used to assess heterogeneity graphically. This tool plots the ratio of the log cumulative survival to its standard error in relation to the reciprocal of the standard error, with the summary log cumulative survival included as a solid line banded by its 95% CI.[24] The location of individual studies in relation to the 95% CI of the log cumulative survival can be seen. In the absence of statistical heterogeneity, 95% of the trials would be expected to lie between these confidence bands. Small trials with less precise results are seen toward the left of the plot, while larger trials with more precise results are seen toward the right. One study[18] lay outside the confidence bands, with results below the expected range. A sensitivity analysis showed that removal of

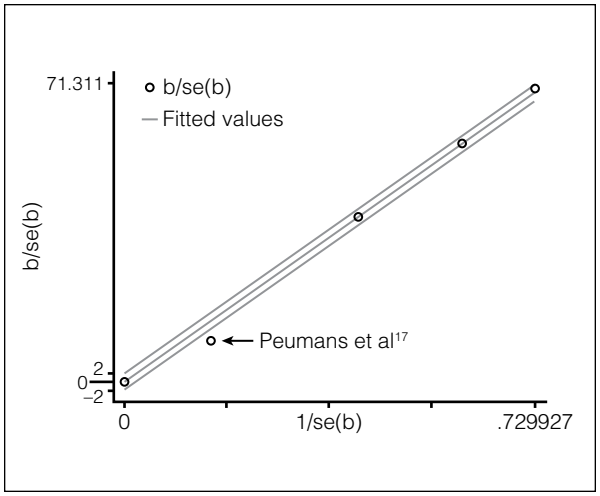



**Fig 7** Galbraith plot showing the 10-year summary log cumulative survival included as a solid line banded by its 95% CI. One study (Peumans et al[17]) lies outside the CI of the plotted statistic.

Peumans et al[18] decreased the statistical heterogeneity and increased the pooled 5-year cumulative survival to 97.3% (95% CI: 95.9% to 98.8%).

The forest plot of the 10-year data shows the survival outcomes of 64%, 95%, and 96% and their associated CIs. Only three studies reported adequate information to quantitatively assess the 10-year outcomes of feldspathic porcelain veneers. A fourth study reported a 10-year estimated cumulative survival of 53%, but insufficient data were available to calculate the standard error. Marked heterogeneity of

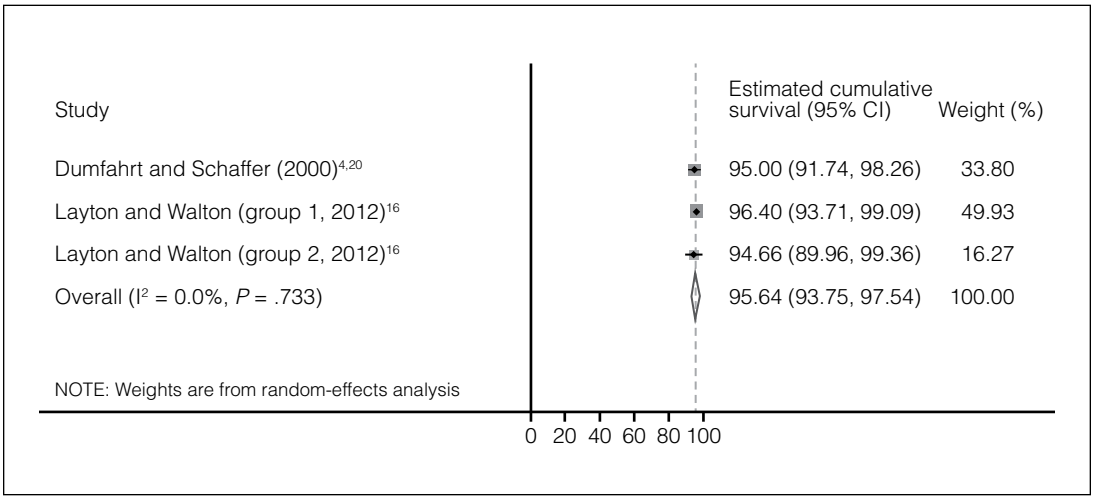



**Fig 8** Sensitivity analysis: 10-year results. The fixed-effects pooled estimate was 95.6% (95% CI: 93.8% to 97.5%) (Cochran Q = 0.62, *df* = 2, *P* = .733, $I^2$ = 0%).

the included studies was found, as assessed by the Cochran Q test and associated *P* value (*P* < .001), $I^2$ statistic (90%), forest plot (CIs of individual studies were widely separated), and Galbraith plot (results from Peumans et al[17] were below the expected range). Removal of Peumans et al[17] from the calculations via sensitivity analysis led to an increase in the summary estimate and a decrease in statistical heterogeneity. Clearly, the outcomes of these studies differ from each other more than can be expected by chance, with the fourth nonincluded study further illustrating the variability in survival. However, with only three results, it is impossible to determine which outcome represents a deviation from the clinical norm, and the presentation of a pooled estimate including some or all of the studies could not be justified.

With access to individual patient data from Layton and Walton,[16] the 20-year results could be divided retrospectively into two 10-year cohorts. Group 1 included 88 patients with 239 veneers (10-year survival = 96% [95% CI: 94% to 99%]), and group 2 included 260 veneers in 67 patients (10-year survival = 95% [95% CI: 90% to 99%]). The divided 20-year data are clustered within a single practice, allowing the consistently high survival rates to be attributed to consistency in the clinical and laboratory techniques.

A retrospective study by Friedman[13] reported a success rate of 93% over 15 years. Although the losses to follow-up were unreported, these results indicate that good clinical survival is achievable over at least 10 years. However, this systematic review also shows that high survival rates are not necessarily consistent across studies. It is important to explore possible reasons for this statistical heterogeneity, which may be related to clinical heterogeneity, methodologic differences, or unknown patient or study characteristics.

Clinical heterogeneity was found, as was expected due to the inclusion criteria for the meta-analysis. The aim of this study was to ascertain the best summary estimate for the survival of feldspathic porcelain veneers within a variety of clinical settings and a range of patients. This aim was broader than that of the individual studies included and thus knowingly incorporated heterogeneity. The included studies each aimed to determine the survival of porcelain veneers given their own inclusion criteria. Research indicates that survival is likely to be decreased when veneers are bonded to reduced enamel substrate[13,17,25] or when patients have a history of parafunction[10,13,25]; therefore, these were considered exclusion factors for some studies. However, these factors were not part of the exclusion criteria for this meta-analysis. This study aimed to produce clinically relevant results by seeking a summary estimate of survival with improved precision and greater applicability. Clinicians are likely to continue both bonding to reduced enamel substrate and providing veneers to patients suffering from parafunction.

Reduced enamel substructure can occur when veneers are partially bonded to retained restorations or to dentin and cementum. Enamel has an improved micromechanical bond in comparison with dentin and cementum,[26] and its high modulus of elasticity[27,28] allows enamel to support the brittle porcelain like a natural substructure. Lack of enamel can be patient-driven, when patients are unwilling to proceed with a full-coverage crown, or operator-driven, when the remaining enamel is considered sufficient by the clinician.

Peumans et al[17] reported that veneer survival dropped from 92% at 5 years to 64% at 10 years. These survival estimates were found to be below the 95% CI of the pooled results at both 5 and 10 years. Removal of this study from the meta-analysis improved the summary estimate and decreased statistical heterogeneity. The 5-year results from Peumans et al[17,18] were retained for quantitative analyses with the random-effects model, but meta-analysis of the 10-year results was not justified because of the marked statistical heterogeneity.

Peumans et al[17] attributed the dramatic decrease in survival to the bonding substrate, with some veneers bonded to retained restorations, bonded to dentin rather than enamel, or not bonded with adhesive cements at all. Together with the authors of the other four quantitative studies, they described at least one exclusion criterion related to bonding substrate (excessive attrition, less than 50% enamel, presence of dentinogenesis/amelogenesis imperfecta, less than 80% enamel, inadequate sound enamel); however, each of the other studies adhesively bonded the veneers. Therefore, it appears that the lack of adhesive cementation in this cohort may have adversely affected the survival of the veneers.

Of the four qualitative studies, one[12] described at least one substrate-related exclusion criterion, and none described the bonding protocol. Burke and Lucarotti[1] reported the lowest survival of all included outcomes. They retrospectively reported the outcome of veneers completed in the general dental services of England and Wales by multiple operators. The authors were therefore unable to describe the clinical methodology employed, but it is likely that veneers placed within this health system may have used poor bonding substrates or been placed in high-risk patients. The reported survival rate of 53% over 10 years is low and markedly different from that of other cohorts. Reporting a standard error or CI would have enhanced the usefulness of this result. Burke and Lucarotti[1] found lower survival rates for veneers placed in men, older patients, patients who did not pay for treatment, and patients who regularly changed dentists. They were unable to analyze the impact of clinical heterogeneity on the outcomes.

The second factor leading to reduced survival rates—the presence of parafunction—is likely to emerge through clinical uncertainty. Parafunction is a chronic condition that fluctuates in severity, and diagnosis of a current episode is likely to be inaccurate without specialized tests. It is probable that patients with undiagnosed parafunctional habits were included within many or all of the study cohorts. Therefore, excluding studies that identified patients with parafunction would likely introduce bias. However, all studies in this systematic review excluded patients who were subjectively deemed to have an excessive parafunctional habit. Therefore, it is unlikely that the presence of an undiagnosed parafunctional habit explains the underlying heterogeneity observed across the studies.

A major source of methodologic heterogeneity in the assessment of dental prostheses is classification of the outcome. Minimizing methodologic outcome heterogeneity was considered essential for this meta-analysis. Many systematic reviews within dentistry have struggled with this problem and have chosen to define survival as "the prosthesis being present, with or without modification."[29,30] However, the current authors believe that this definition of survival is too broad and clinically irrelevant. Therefore, for this review, survival was defined using the six-field protocol.[21] The results from individual studies were reviewed, reclassified, and extracted for re-analysis if required. Re-analysis was time consuming but considered imperative for the interpretation of the results.

The choice of summary estimate also influences methodologic heterogeneity. The data could have been expressed as events per 100 veneer years or as cumulative survival at particular time points using time-to-event analyses. The latter method was chosen. Use of events per 100 veneer years is commonly employed when assessing dental prostheses, but this method suffers from the assumption of a constant annual event rate throughout the follow-up period. Although all studies included in the meta-analysis followed veneers for up to 5 or 10 years, the mean observation period for each study varied. Restorations, including veneers, are expected to fail as time progresses. Thus, average annual failure rates are likely to be higher in studies with a greater mean follow-up because of the greater contribution of data from later years.

The presence of cluster failures may also influence methodologic heterogeneity. The data reported by each study included multiple veneers within the same individual, with the outcomes reported per restoration and not per patient. This leads to clustered data. There is no reason to believe that the success or failure of a single veneer is independent from the outcomes of other veneers in the same patient. One way to account for clustering is to randomly identify one restoration in each patient and report its outcome[31]; however, this procedure was not carried out in most of the studies, and performing it post hoc would require individual participant and veneer data. Although this methodologic shortcoming is present in all included studies, it is still likely to influence heterogeneity because it may affect different studies in different ways.

Other unknown or unreported clinical or methodologic differences between the studies could also have contributed to the statistical heterogeneity. The included studies were carried out in different treatment settings (hospital, university, private practice) by clinicians of different skill levels (students, dentists, specialists) and with different patients. At the setting level, restorative outcomes are affected by access to clinical materials, major equipment, and dental specialists. At the clinician level, restorative outcomes are affected by diagnostic judgment and technical proficiency. At the patient level, outcomes are affected by numerous factors, including medications, systemic disorders, oral hygiene, diet, salivary quality, periodontal susceptibility, current caries activity, tooth structural integrity, and parafunctional habits. Differences in such variables can impact veneer outcomes. However, there were insufficient data regarding these and other possible influencing factors to conduct further qualitative or quantitative analysis of heterogeneity.

As stated, the 5-year results were combined quantitatively with the random-effects model, and the 10-year results were not pooled. It is important to explore the mathematics of the random-effects model in relation to the included studies. The random-effects model places more weight on the results of smaller studies. By chance, smaller studies may include the extremes of a treatment effect, with statistically significant small studies more likely to be published than nonsignificant ones.[32] Thus, the presence of publication bias (which would favor the availability of small, outlying studies) could bias the pooled estimate of the random-effects model.

A funnel plot was constructed to explore publication bias and other biases associated with small studies. Although the studies were moderately well distributed around the point estimate, there were too few studies to reliably assess bias. At 5 years, one large study[18] was outside the expected results, and one small study with an estimate above 98% may possibly be missing. Given this presentation, it is unlikely that the pooled estimate from the random-effects model has been artificially inflated by a small, positively skewed study; in fact, the pooled estimate may be conservative.

The robustness of the 5-year random-effects pooled estimate (94.7% [95% CI: 92.6% to 96.8%]) was explored by comparing it with the pooled estimate from the fixed-effects model (95.1% [95% CI: 94.1% to 96.1%]). In absolute terms, the pooled estimate increased by almost 0.5%, and the 95% CI tightened by 2%. The difference between these pooled estimates was not clinically significant.

## Conclusions

The summary estimated cumulative survival for feldspathic porcelain veneers was 95.7% (95% CI: 92.9% to 98.4%) at 5 years and ranged from 64% to 95% at 10 years across three studies. A post hoc meta-analysis indicated that the 10-year best estimate may approach 95.6% (95% CI: 93.8% to 97.5%). The high levels of statistical heterogeneity found may be related to both clinical and methodologic differences among the included studies. In particular, the partial bonding of porcelain veneers to reduced enamel may be associated with decreased estimated cumulative survival rates. Care should be taken by future researchers to ensure that tooth characteristics and censoring are well described, the precision of the calculated summary estimate is reported, survival definitions are clinically relevant, and clustered outcomes are correctly analyzed.

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*Literature Abstract*

**Short dental implants: A systematic review**

Short implants have been proposed as an option for restoring atrophic ridges since they may provide surgical advantages by reducing morbidity, treatment time, and costs. The rationale behind the use of short implants is that the crestal portion of the implant body bears most of the load, whereas relatively little load is transferred to the apical portion. Hence, implant length may not be a primary factor in distributing prosthetic loads to the bone-implant interface. This systematic review aimed to evaluate clinical studies that used implants that were less than 10-mm long to support an implant prosthesis in atrophic arches. Implant survival, implant biologic success, radiographic peri-implant marginal bone loss, and implant biomechanical success were evaluated. The two randomized controlled trials and 14 observational studies that met the selection criteria were independently screened by two reviewers. Meta-analyses were performed by pooling survival data based on the implant surface, surgical technique, implant location, type of edentulism, and prosthetic restoration. A total of 6,193 implants were investigated, and the observational period was 3.2 ± 1.7 years. The pooled cumulative survival rate was 99.1%, the pooled biologic success rate was 98.8%, and the pooled biomechanical success rate was 99.9%. The cumulative survival rate was higher in rough-surface implants compared to machined implants. Although short implants have been considered less reliable compared to standard-length implants, this review of recent publications indicates that successful results can be obtained with short implants in terms of implant survival. Surgical technique, implant location, and the type of edentulism did not seem to affect the survival of short implants, and most failures occurred before prosthesis placement. This suggests that bone quality and suitable surgical protocols may play an important role in the success of short implants. The results of this systematic review suggest that short implants may be a viable alternative in atrophic ridges.

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